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October 9, 2000
NSRP 0565
N5-98-1

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

Ergonomic Study of Shipbuilding and Repair

U.S. DEPARTMENT OF THE NAVY
CARDEROCK DIVISION,
NAVAL SURFACE WARFARE CENTER

in cooperation with
National Steel and Shipbuilding Company
San Diego, California

Report Documentation Page	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
09 OCT 2000	**N/A**	**-**

4. TITLE AND SUBTITLE **The National Shipbuilding Research Program, Ergonomic Study of Shipbuilding and Repair**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Surface Warfare Center CD Code 2230-Design Integration Tower Bldg 192, Room 128 9500 MacArthur Bldg Bethesda, MD 20817-5700**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**603**	

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PROJECT REPORT

ERGONOMIC STUDY OF SHIPBUILDING
AND
SHIP REPAIR

NS98-01

OCTOBER 09, 2000

SUBMITTED BY: KARL V SIEGFRIED
MAINE EMPLOYERS' MUTUAL INSURANCE COMPANY

MEMIC
Partners for Workplace Safety℠

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INTRODUCTION:

Due to the high volume of multi-faceted job tasks performed by the various construction trades in the shipbuilding and ship repair industry, there is a perception that fitting the job to the worker may not be practical or applicable. In addition, ergonomic controls used in general industry are not unilaterally employable because of the diverse job activities found in these construction trades. However, because of the high injury and illness rates in this industry, it is imperative that research be undertaken to better understand the relationship between the high rate of injuries and illnesses, as noted in the OSHA 200 Logs, and associated job risk factors. Once this association is better understood, effective ergonomic intervention strategies in the form of guidelines can be developed to prevent such injuries and illnesses. Dissemination of these guidelines will be done through the NIOSH partners such as the Maritime Advisory Committee on Occupational Safety and Health (MACOSH), OSHA, shipyard construction companies, and labor unions.

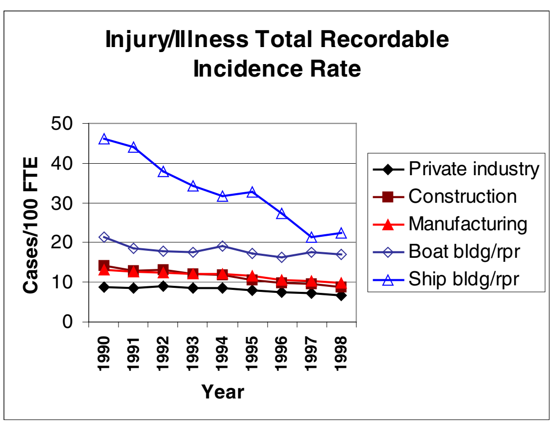
In 1998, SP5 panel funded project 98-01, "Ergonomic Study of Shipbuilding and Ship Repair", which closely paralleled a project undertaken by the National Institute of Occupational Safety and Health (NIOSH), "Shipyard Ergonomic Project". It was determined early on in the SP5 project that marrying the two projects would yield greater overall effectiveness toward achieving the long-range goal of developing consensus ergonomic guidelines for the domestic shipbuilding and repair industries.

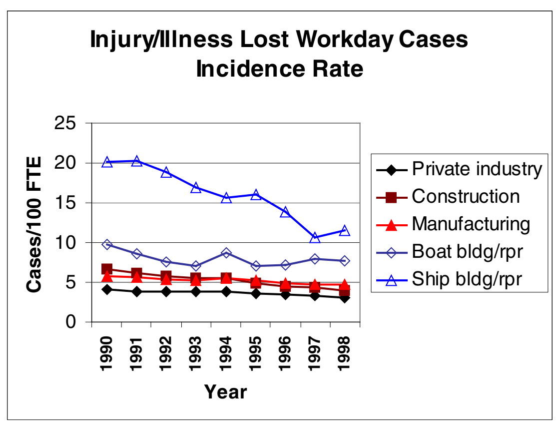
The general objective is to determine if the implementation of ergonomic interventions within the domestic shipbuilding, repair, and recycling industries can increase product quality and productivity, while reducing injuries and illnesses and Workers' Compensation costs to the point of being beneficial to the industry's position in the global market.

This project was originally split into three phases. Phase one (funded by SP5) involved the selection process for participating yards, the initial injury/illness records analysis, identification of high risk areas and/or job tasks, and scheduling of qualitative and quantitative analysis of high risk occupations. Phase two involves the pre-intervention quantitative analysis of up to three problem jobs in each participating yard, identification of engineering and/or administrative ergonomic interventions/controls, and piloting these interventions to assure desired result(s) are achieved. Phase three includes a cost benefit analysis of each implemented intervention strategy to document success/failure of modification. This will include injury tracking in the area of incidence and severity rates, Workers' Compensation costs, changes in labor hours, quality, and so forth. The final report will be in the form of consensus ergonomic guidelines for the domestic maritime industry.

BACKGROUND FOR THIS STUDY

The domestic ship building, ship repair, and ship recycling industries have historically had much higher injury/illness incidence rates than those of general industry, manufacturing, or construction. For 1998, the last year available, the Bureau of Labor Statistics reported that shipbuilding and repair (SIC 3731) had a recordable injury/illness incidence rate of 22.4 per 100 full-time employees (FTE), up from 21.4 in 1997. By contrast, in 1998, the manufacturing sector reported a rate of 9.7 per 100 FTE, construction reported a rate of 8.8 per 100 FTE, and all industries reported a rate of 6.7 injuries/illnesses per 100 FTE. When considering only lost workday cases, for 1998, shipbuilding and repair had an incidence rate of 11.5 per 100 FTE, compared to manufacturing at 4.7, construction at 4.0, and all industries at 3.1 lost workday injuries/illnesses per 100 FTE.





When comparing shipbuilding and repairing to the manufacturing sector for injuries and illnesses to specific parts of the body resulting in days away from work, for the year 1997, shipbuilding is significantly higher in a number of instances. For injuries and illnesses to the trunk including the back and shoulder, shipbuilding reported an incidence rate of 207.7 cases per 10,000 FTE, compared to manufacturing at 82.1 cases. For injuries and illnesses solely to the back, shipbuilding reported 111.1 cases per 10,000 FTE, compared to manufacturing's incidence rate of 52.2 cases. For the lower extremity, shipbuilding reported 145.0 cases per 10,000 FTE compared to manufacturing at 40.8 cases. For upper extremity injuries and illnesses, shipbuilding reported an incidence rate of 92.2 cases per 10,000 FTE while manufacturing reported 73.4 cases.

When comparing shipbuilding and repairing to the manufacturing sector for injuries and illnesses resulting in days away from work, for the year 1997, by nature of injury, shipbuilding is significantly higher in a number of categories. For sprains and strains, shipbuilding reported an incidence rate of 237.9 cases per 10,000 FTE, compared to manufacturing's incidence rate of 91.0 cases. For fractures, shipbuilding reported 41.7 cases per 10,000 FTE, compared to manufacturing at 15.8 cases. For bruises, shipbuilding reported 61.3 cases per 10,000 FTE, compared to manufacturing at 21.5 cases. The median number of days away from work for shipbuilding and repairing is 12 days, compared to manufacturing and private industry's median of 5 days.

Beginning in 1995 the National Shipbuilding Research Program began funding a project looking at the implementation of ergonomic interventions at a domestic shipyard as a way to reduce

Workers' Compensation costs and to improve productivity for targeted processes. That project came to the attention of the Maritime Advisory Committee for Occupational Safety and Health (MACOSH), a standing advisory committee to the Occupational Safety and Health Administration (OSHA). The National Institute for Occupational Safety and Health (NIOSH) began an internally funded project in 1997 looking at ergonomic interventions in new ship construction facilities. In 1998, the U.S. Navy decided to fund a number of research projects looking to improve the commercial viability of domestic shipyards, including projects developing ergonomic interventions for various shipyard tasks or processes. Project personnel within NIOSH successfully competed in the project selection process. The Institute currently receives external project funding from the U.S. Navy through an organization called Maritech Advanced Shipbuilding Enterprise, a consortium of major domestic shipyards.

Shipyards participating in this project will receive an analysis of their injury/illness data, will have at least one ergonomic intervention implemented at their facility, and will have access to a website documenting ergonomic solutions found throughout the domestic maritime industries. The implementation of ergonomic interventions in other industries has resulted in decreases in Workers' Compensation costs, and increases in productivity.

Researchers will identify seven participating shipyards and analyze individual shipyard recordable injury/illness databases by the end of November 1999. Ergonomic interventions will be implemented in each of the shipyards by the end of June 2000. Intervention follow-up analysis will be completed by the end of December 2000. A series of meetings and a workshop to document the ergonomic intervention program will be held by the end of March 2001.

PROJECT PARTNERS

We are fortunate to have the following partners working with the project team on this important study. These partnerships will help the project team obtain assistance and technical support from the participating shipyards. Without the full cooperation of project shipyards, project deliverables will be compromised.

- National Institute for Occupational Safety and Health (NIOSH), Centers for Disease Control and Prevention (CDC), Public Health Service, Department of Health and Human Services
- National Shipbuilding Research Program (NSRP)/MARITECH Advanced Shipbuilding Enterprise
- Maritime Advisory Committee for Occupational Safety and Health (MACOSH)
- Occupational Safety and Health Administration, Ergonomic Team
- Labor: Boilermakers, IBEW, Metal Trades Council, AFL-CIO
- National Shipyard Association/Shipbuilders Council of America

- Occupational Safety and Health Administration (OSHA)

- U.S. Navy, Naval Sea Systems Command (NAVSEA)

- U.S. Navy, Office of Naval Research, Maritime Industrial Practices (ONR)

- U.S. Coast Guard

- U.S. Maritime Administration (MARAD), Department of Transportation

PHASE ONE

SHIPYARDS VISITED

Following is a list of shipyards visited by the team. The purpose of these walk-through visits was to orient NIOSH team members to the shipbuilding and ship repair process as well as to select yards for participation in this project. After meeting with the OSHA Ergonomic Team in March of this year, additional small shipyards may be added to the current roster at their request and recommendation. An asterisk denotes the eight companies selected to be active participants in the on-site evaluations for this project.

- ASTORIA METAL (NIOSH HHE)
- BATH IRON WORKS *
- CASCADE GENERAL
- CONTINENTAL MARITIME *
- ELECTRIC BOAT GROTON & QUONSET POINT
- HALTER MARINE *
- INGALLS *
- JEFF BOAT *
- NASSCO
- NEWPORT NEWS
- PUGET SOUND NAVAL SHIPYARD *
- TODD *

- MARINET MARINE *

*Indicates yards taking an active role in the project.

Three main criteria were used in the selection process. They are as follows:

1. Willingness to share all necessary background data to include injury trends and costs over a three-year period.
2. Availability of an on-site representative to assist teams with data collection, qualitative and quantitative analysis, and the implementation of control strategies, i.e., engineering and/or administrative controls.
3. Currently performing job tasks/processes which contain ergonomic hazards.

In addition to the above criteria, also taken into consideration was size of shipyard, feasibility of roadblocks (management problems and/or labor disputes), and demographics. Our goal is to involve as diverse a group as possible to cover all aspects of the maritime industry. Ideally, we will be investigating the shipbuilding process from keel to mothballs.

PROJECT PRESENTATIONS

The Ergonomic Study of Shipbuilding and Ship Repair project has been successfully presented at the following locations:

MACOSH Meeting in Washington, DC (workshop)

OSHA Ergonomics Team (Washington, DC)

National Safety Congress (Los Angeles, California)

Applied Ergonomics Conference (Houston, Texas)

Ergonomics Reducing the Risk (Lowell, Massachusetts)

National Industrial Engineers Conference (Phoenix, Arizona)

AIHA Conference (Toronto, Ontario, Canada)

The purpose of the presentations was to gain support of necessary parties for the project. That this has been very successful is marked by Labor Charles Jeffress, the Assistant Director of and Linda Rosenstock, head of the National Institute of Occupational Safety and Health, speaking to the project and voicing their support in Houston.

Technical Progress

Following is the Technical Status Report for the project. Technical efforts for the period _September 10, 1999_ through _December 31, 1999_ include:

- ATI and NIOSH sign Technology Investment Agreement # 20000170 on September 10, 1999
- Held informal advisory meeting with sub-group of the Safety and Health Advisory Committee (SHAC) of the Facilities and Tooling major initiative area in Cincinnati, OH on September 21, 1999
- Met with faculty of the Institute for the Study of Human Vibration from the University of Tennessee in Cincinnati, OH on September 21, 1999 concerning testing of powered hand tools
- Held project kick-off meeting in Cincinnati, OH on October 4, 1999
- Conducted Pre-Intervention Quantitative Risk Factor Analysis at Puget Sound Naval Shipyard in Bremerton, WA on October 19-22, 1999
- Program Management Plan was produced and submitted as Milestone # 1, Deliverable # 1 on October 25, 1999
- Conducted informational meeting with Jeffboat in Jeffersonville, IN on October 27, 1999
- Conducted Pre-Intervention Quantitative Risk Factor Analysis at Jeffboat in Jeffersonville, IN on November 9-10, 1999
- Provided update on project to Maritime Advisory Committee on Occupational Safety and Health (MACOSH) at their meeting in Annapolis, MD on November 17, 1999
- Draft Composite Injury/Illness Analysis Report from Participating Shipyards was produced and submitted as Milestone # 2, Deliverable # 1 on November 24, 1999
- Conducted Pre-Intervention Quantitative Risk Factor Analysis at Halter Marine Group Moss Point facility in Moss Point, MS on November 29-30, 1999
- Progress continues on draft PIQRFA reports for Puget Sound Naval Shipyard, Jeffboat, and Halter Marine Moss Point as Milestone # 3, Deliverables # 1, 2, 3, due January 31, 2000

- Commenced Workers' Compensation Data Analysis of 2 Shipyards as part of Milestone # 7 due June 30, 2000
- Commenced work on development of website of ergonomic solutions as part of Milestone # 10 due January 31, 2001

Problems

- Initial scheduling of yards as in Program Management Plan altered according to availability of yards and availability of projects within those yards. Initially only Puget Sound Naval Shipyard was scheduled, others listed alphabetically. Recommend that Puget Sound Naval Shipyard, Jeffboat and Halter Marine Moss Point are considered to be first group. Other yards as second group.
- Videotape of Puget Sound Naval Shipyard facilities still undergoing U.S. Navy security review due to nature of facility. Tapes have cleared review within PSNS and are enroute to HQ, Washington, DC for review. Delays in subsequent data analysis and report expected because of this review.

Technical Issues

There have been no technical issues identified that impact the current program progress.

Major Developments

- On November 23rd, 1999, the Occupational Safety and Health Administration (OSHA) published the Proposed Rule for Ergonomics Programs for General Industry in the Federal Register. This proposed rule exempts the maritime industries, in part, because of the existence of the current project.

Plans for Next Quarter

- Attend meeting of the sub-committees of the Facilities and Tooling major initiative areas in Orlando, FL in February 2000
- Conduct 4th and 5th Pre-Intervention Quantitative Risk Factor Analysis at 2 of 4 remaining yards (BIW, Continental Maritime, Ingalls, and Todd Pacific) by March 31, 2000.
- Implement ergonomic interventions at 4 shipyards by March 31, 2000

COMPLETED DELIVERABLES

Shipyard visits to date entailed a cursory walk-though of the facility, meeting with management and safety professionals who will be working with the project team. When we started the project team members included NIOSH project manager Dr. Steve Hudock, Thomas Hales MD, James McGlothlin, Steve Wesinbaucher, and Karl Siegfried, project manager for NSRP. As of January 1st, Steve Hudock took over as project leader from James McGlothlin, who has taken a position with Purdue University.

During the shipyard walk-though we looked at the overall shipbuilding and ship repair process, keying on job tasks/functions that require workers to perform risk factors that are associated with the development of musculoskeletal disorders. In addition, we identified ergonomic interventions that have been implemented.

The primary risk factors of awkward postures and positioning and tasks requiring the expenditure of excessive force consistent in each of the yards visited. The amount of work performed above shoulder level and below knee height is commonplace. Workers are also exposed to high levels of hand-arm vibration. What we do not know at this point is the frequency range employees using antiquated tools are exposed to. Phase two and three of this project will involve vibration spectrum testing to determine current levels as well as document effectiveness of new tools and/or other vibration dampening techniques.

Through correspondence we asked each of the participating shipyards to identify high-risk areas for ergonomic injuries within their facilities. The goal is to investigate two, to three different problem jobs at each participating shipyard. This should supply the team with enough substantial information necessary to develop consensus guidelines for the maritime industry. Following is a sample of the correspondence sent to Bath Iron Works to request information.

MEMIC
Partners for Workplace Safety™

May 10, 1999

Chris Barbor, COHN

Bath Iron Works

700 Washington Street

Bath, Maine 04530-2556

RE: NIOSH-NSRP Ergonomic Intervention Study - Injury and Illness Records

Dear Chris,:

Thank you for your letter dated January 11, 1999 identifying high risk areas for ergonomic injuries within Bath Iron Works. As you are aware, NIOSH does not have the resources, financial or personnel, to investigate all jobs or tasks with the potential for creating ergonomic hazards. Therefore, jobs or tasks will be prioritized for NIOSH ergonomic analysis and subsequent intervention. This prioritization, or ranking, will be based on input from the following sources:

1. Employers;
2. Employees or their representatives;
3. NIOSH qualitative assessment (e.g. walk-through survey); and
4. Injury and Illness Records.

The use of injury and illness records will involve analysis of OSHA 200 Logs, OSHA 101 Logs or similar data, labor hours, and workers compensation costs for the past five years, 1994-1998. Analysis of these records can provide insight for the number, rate, severity, and cost of ergonomic injuries. For NIOSH published reports, this data will be combined and condensed with that of other shipyards to preclude the linking of data with an individual shipyard.

From the OSHA 200 Logs, we need the following information:

Number of injuries/illnesses

Number of musculoskeletal (MS) injuries/illnesses

Injury/illness injury rates

MS injury/illness rates

Number of Lost Day or Restricted Work injuries/illnesses cases

Number of Lost Day or Restricted Work MS injuries/illnesses cases

Total number of Lost or Restricted Workdays from all injuries/illnesses

Total number of Lost or Restricted Workdays from MS injuries/illnesses

Types of injuries and illnesses defined as "musculoskeletal" will vary between shipyards. The following conditions are generally considered to by MS conditions: sprain, strain, carpal tunnel syndrome, tendinitis, epicondylitis, bicipital tendinitis, rotator cuff tendinitis, disorders due to repetitive trauma, repetitive motion syndrome, low back pain, other lower extremity disorders, etc. Additional conditions could include: amputation, crushing, dislocation, fracture, contusion, and rupture.

To be useful, this data will need to be broken down by:
phase of construction (part fabrication or assembly, sub-block or block assembly, hull erection on-block outfitting, or on-board outfitting); or phase of repair (repair and overhaul, conversion/modernization, deactivation, and scrapping); and department; occupation; and task.

We have enclosed forms to enter this information, or, preferably, your data can be forwarded to us electronically, perhaps in an Excel spreadsheet.

As mentioned earlier we need to understand the cost of these disorders to your shipyard and the domestic shipbuilding and repair industry as a whole.. Thus, we will need workers compensation costs (medical and indemnity) for both injuries/illnesses and MS injuries/illnesses for the five year period 1994-1998 broken down by the same categories as mentioned above.

Finally, as you may be aware, NIOSH was successful in competing for Maritech ASE funding to supplement our internal funding for this project. As part of the requirements of the Maritech funding, we ask that you begin to track the number of personnel hours and approximate cost for any effort by Bath Iron Works personnel on this project. This information will be used to compile the cost-share requirement from the participating shipyards. We thank you in advance for your cooperation and look forward to working with you this summer. If you have any questions, please do not hesitate to contact us.

Sincerely,

Stephen Hudock, Ph.D., CSP
Shipyard Ergonomics Project Officer
NIOSH
(513) 841-4385

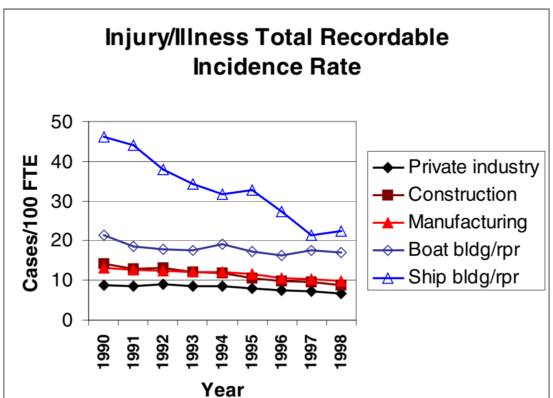
Thomas Hales, MD, MPH
Health Hazard Evaluation (HHE) Program
NIOSH
(513) 841-4583

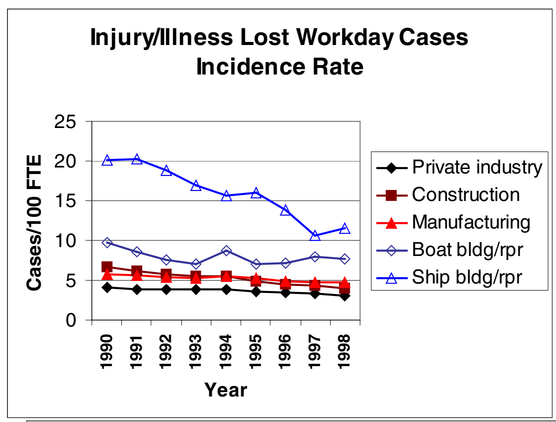
Karl Siegfried, BS, CECD
MACOSH Project Manager
Maine Employers' Mutual Insurance Company
(207) 791-3447

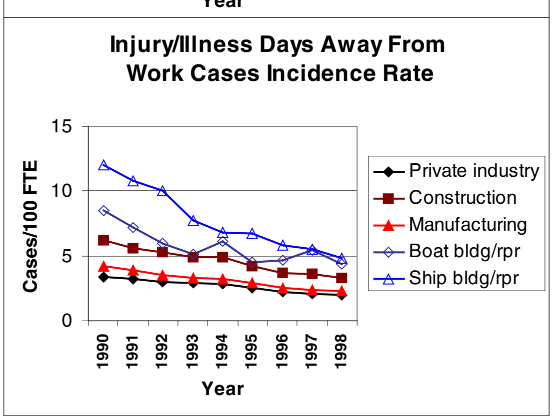
PHASE TWO

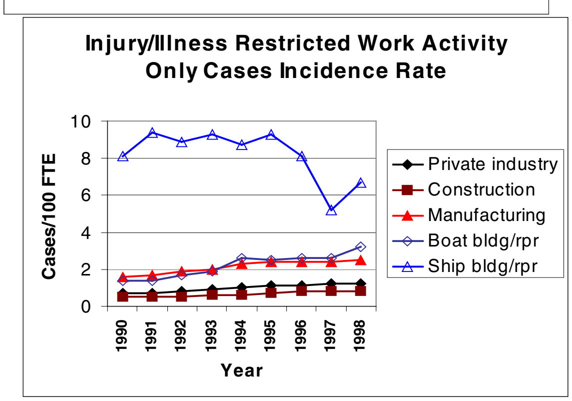
INJURY ANALYSIS

Phase two entailed compiling injury and illness data for each of the participating yards. Purpose of this analysis is not to compare one yard with other. Instead the data was used to help target the team on the problems area within each participating yard. In addition, each shipyard has the ability to compare their injury rates with those on a national average. The difficulty we had was extracting the musculoskeletal disorders from the more traumatic injuries. Since this project addresses injuries being sustained from ergonomic stressors, identifying and extracting soft tissue injuries is vital information required to establish baselines and to measure the success and/or failure of intervention strategies. Below are graphs containing information from the Bureau of Labor Standards and compares multiple industries.





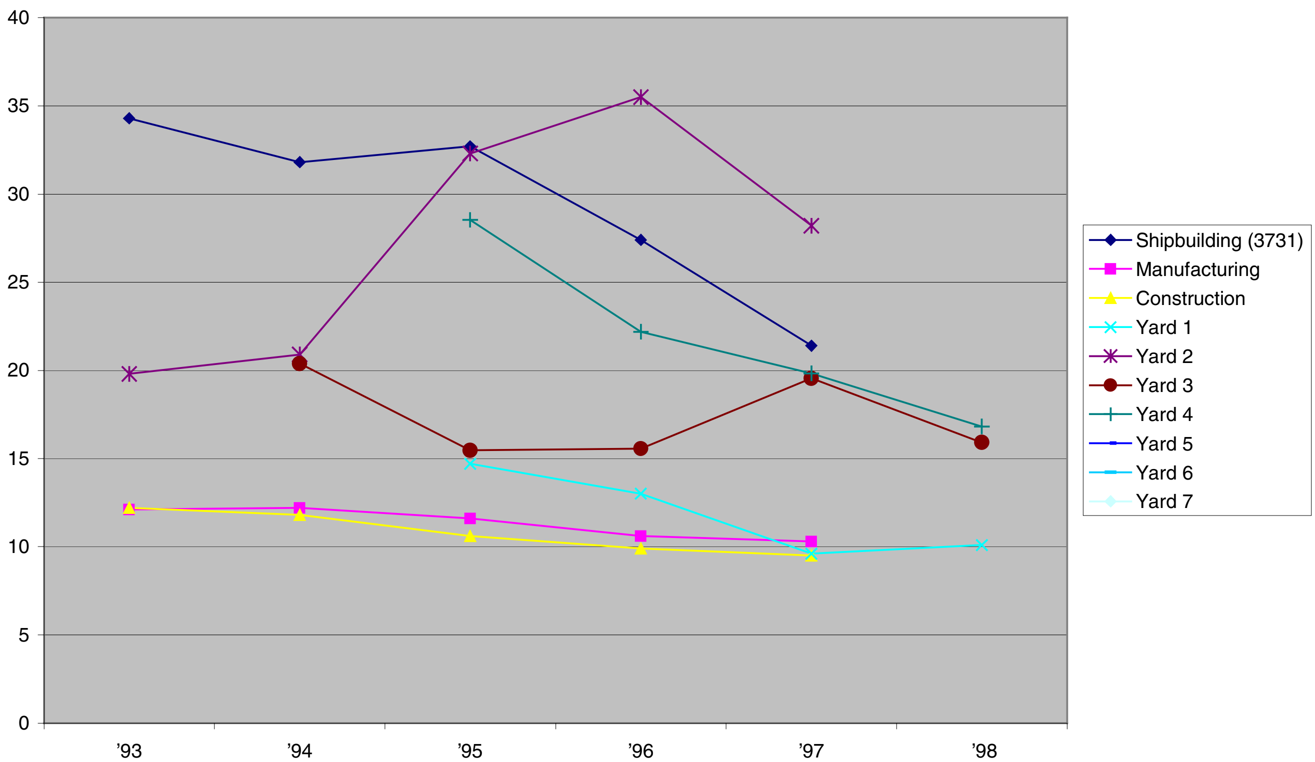




Graph below depicts participating yards as compared to national averages for incidence rates.

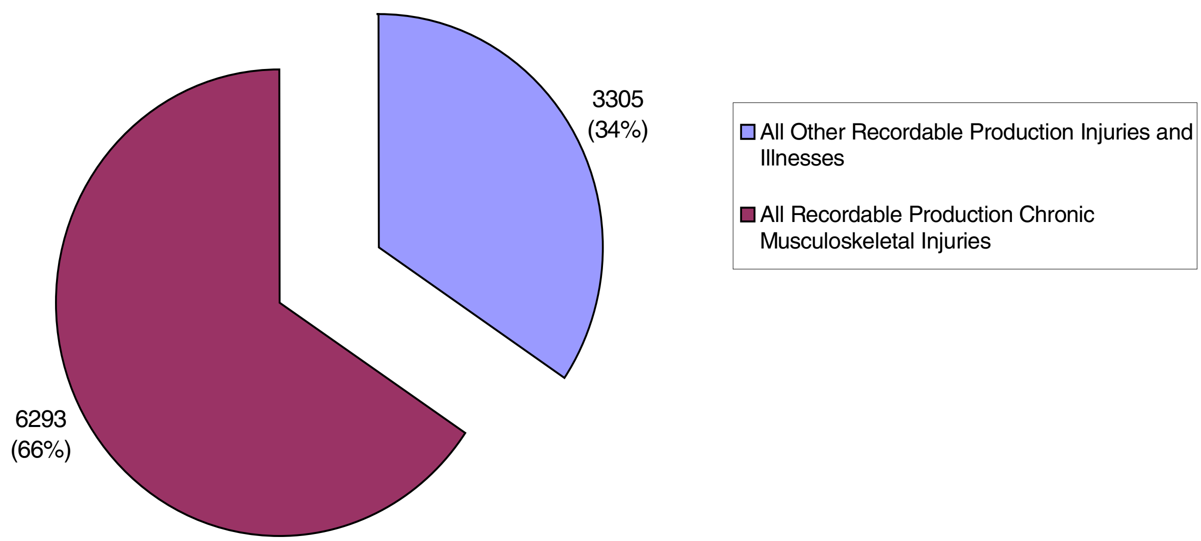
Yards are not listed by name for confidentiality purposes.

Comparison of Incidence of Recordables per 100 Workers by Shipyard
(Based on Total Yard Manhours)



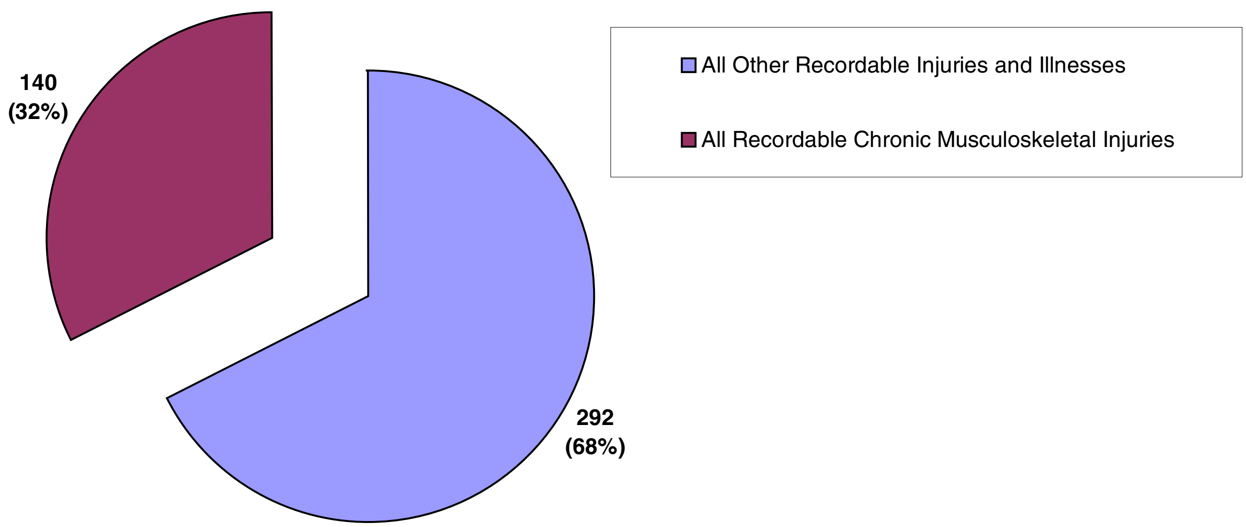
Following is a breakdown by Shipyard of musculoskeletal disorders

Figure A-3
Percentage of Musculoskeletal Disorders Among Production Workers
1994-1998, Shipyard One



Percentage of Recordable Injuries and Illnesses[1] Among Workers which are Chronic[3] Musculoskeletal,1993-September 1998, Shipyard Two

[1] OSHA 200 Logs
[3]Chronic Musculoskeletal Injuries do not Include Contusions and Fractures



Percentage of Recordable Injuries and Illnesses[1] Among Workers which are Chronic[3] Musculoskeletal,1993- August 1999, Shipyard Three

[1] OSHA 200 Logs
[3]Chronic Musculoskeletal Injuries do not Include Contusions and Fractures

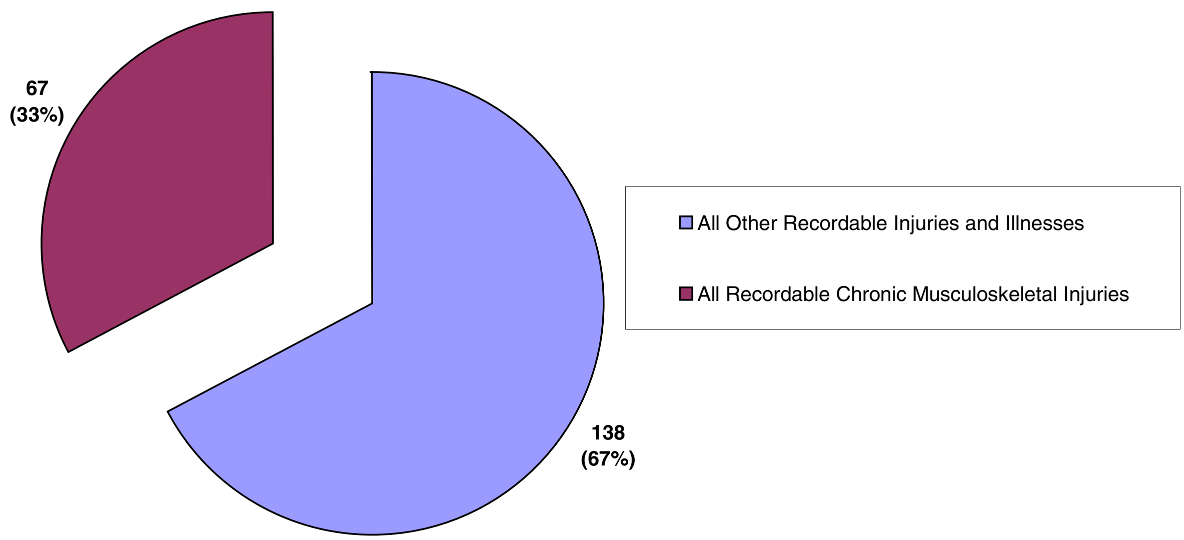


Figure E-3
Percentage of Musculoskeletal Disorders[1]
Among Production Workers
1994-1998, Shipyard Four
[1] OSHA 200 Logs

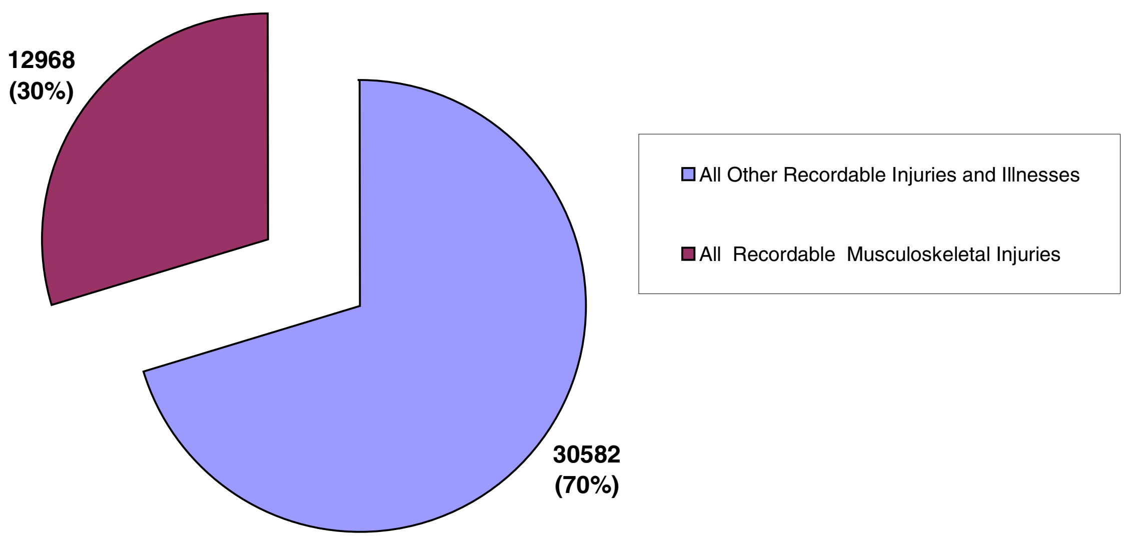


Figure E-3
Percentage of Musculoskeletal Disorders[1]
Among Production Workers
1995-1998, Shipyard Five
[1] OSHA 200 Logs

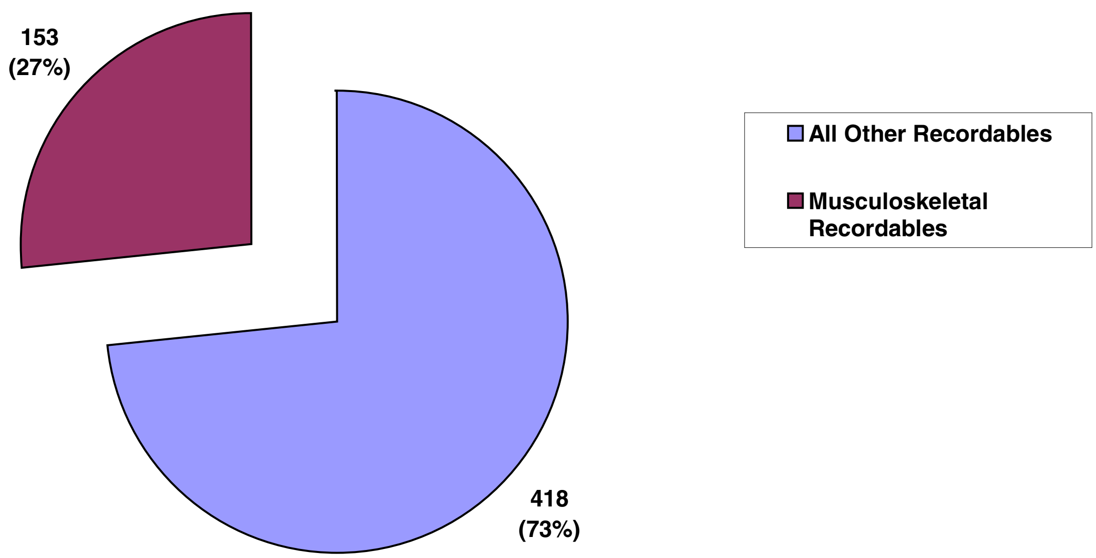
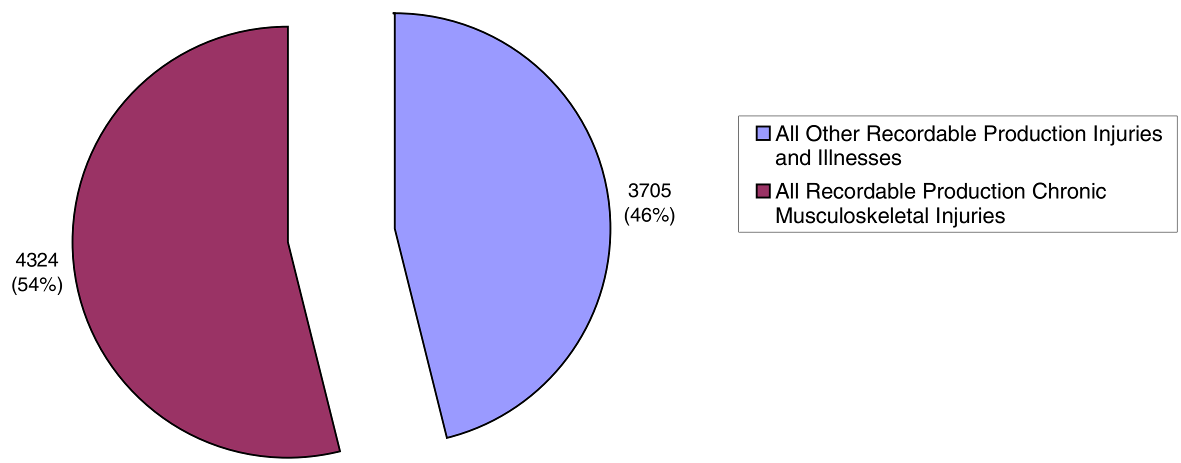


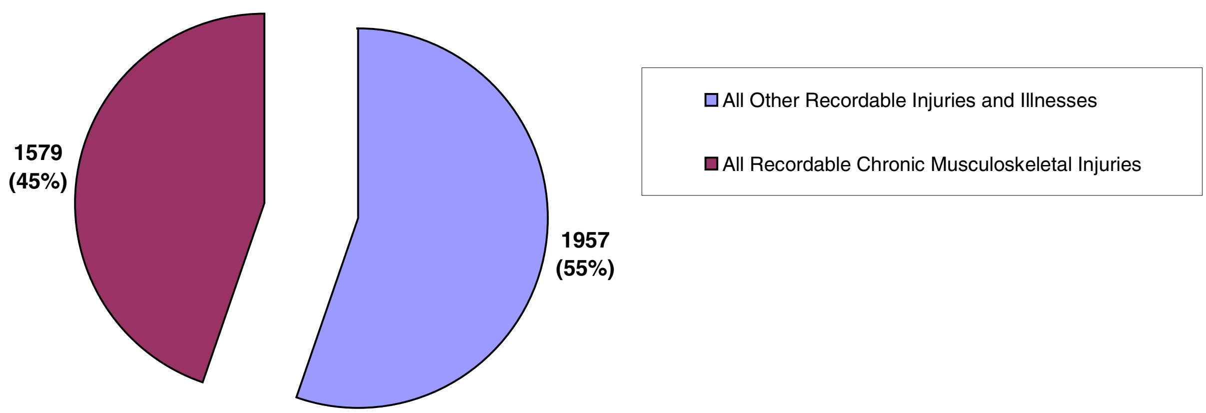
Figure F-3
Percentage of Musculoskeletal Disorders Among Production Workers
1994-1998, Shipyard Six

[1] OSHA 200 Logs

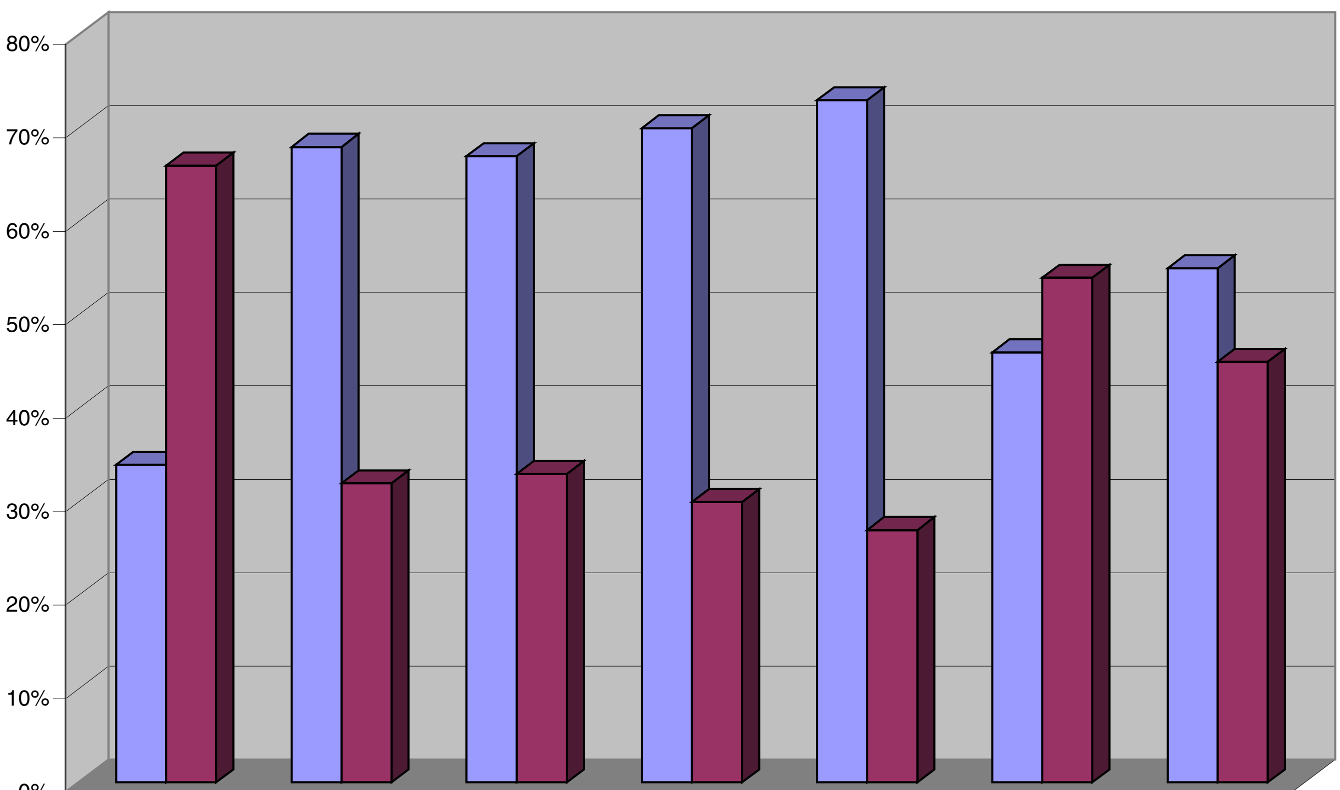


Percentage of Recordable Injuries and Illnesses[1] Among Workers which are Chronic3 Musculoskeletal, 1994- 1998, Shipyard Seven

[1] OSHA 200 Logs
[3]Chronic Musculoskeletal Injuries do not Include Contusions and Fractures



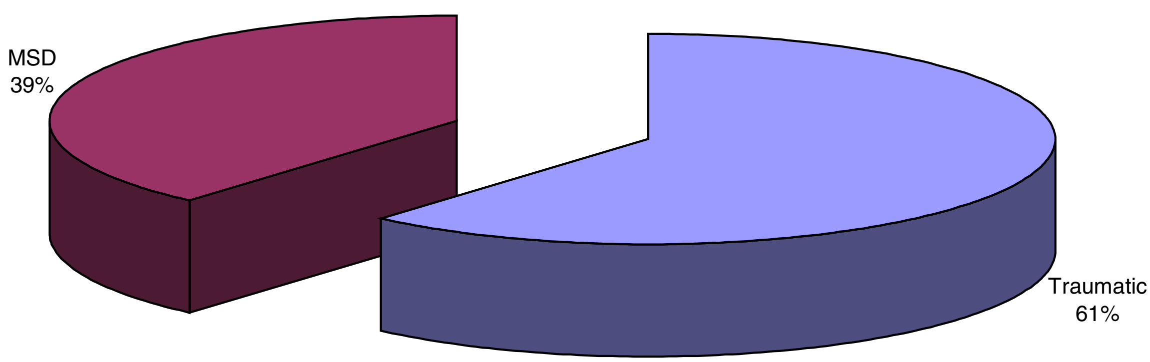
Percentage of Musculoskeletal Disorders Among Production Workers By Shipyard



	Shipyard 1	Shipyard 2	Shipyard 3	Shipyard 4	Shipyard 5	Shipyard 6	Shipyard 7
Traumatic	34%	68%	67%	70%	73%	46%	55%
MSD	66%	32%	33%	30%	27%	54%	45%

Table above breaks out traumatic and non-traumatic injuries and illnesses across various years for all of the shipyards.

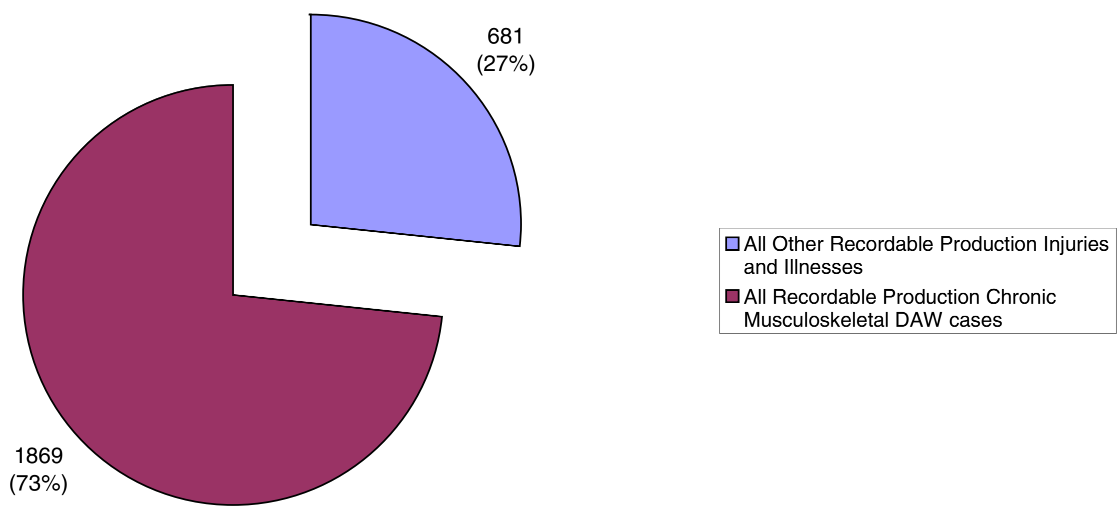
Percentage of Musculoskeletal Disorders Among Production Workers
All Shipyards Combined



Pie Chart above was calculated by combining all shipyards breaking out the musculoskeletal disorders from the traumatic injuries and illnesses. Overall 39% of injuries and illnesses from the represented yards are in fact musculoskeletal and could therefore be positively impacted through sound ergonomic control strategies.

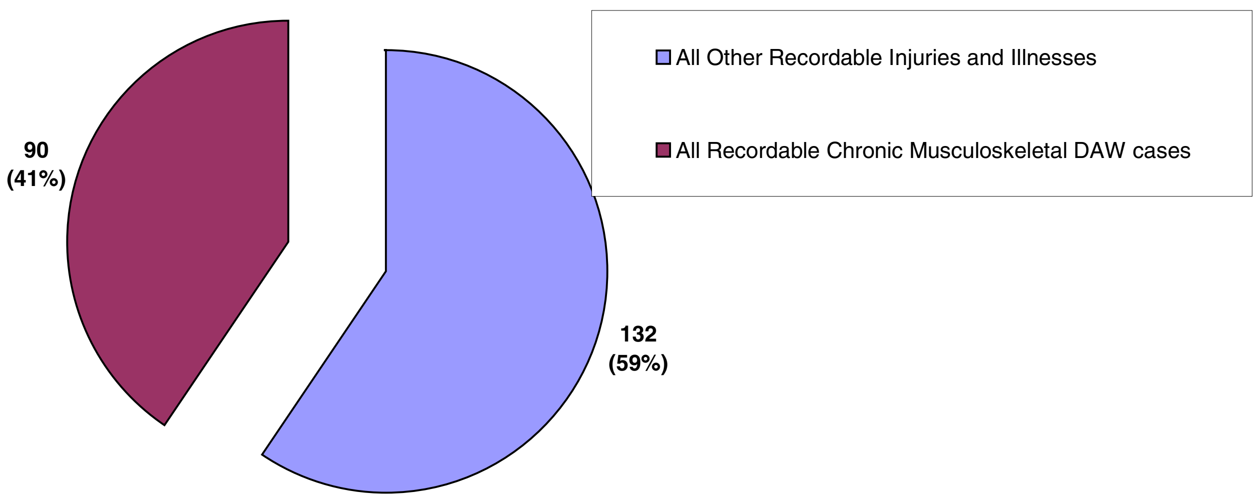
This group of charts compares Injury and Illnesses resulting in Days Away From Work (lost time injuries) for both Traumatic and Musculoskeletal Disorders. Again, Yards are not listed by name for confidentiality purposes. Shipyard(s) four & seven have not supplied us with the data required to be included in this portion of the analysis.

Figure A-4
Percentage of Musculoskeletal Disorders
Involving Days Away from Work (DAW) Among Production Workers
Shipyard One
1994-1998



Percentage of Recordable Injuries and Illnesses[1] Among Workers Involving Days Away from Work which are Chronic[3] Musculoskeletal in Nature, Shipyard Two 1993-September 1998,

[1] OSHA 200 Logs
[3] Chronic do not Include Contusions and Fractures



Percentage of Recordable Injuries and Illnesses[1] Among Workers Involving Days Away from Work which are Chronic[3] Musculoskeletal in Nature,
Shipyard Three
1993-August 1999

[1] OSHA 200 Logs
[3]Chronic do not Include Contusions and Fractures

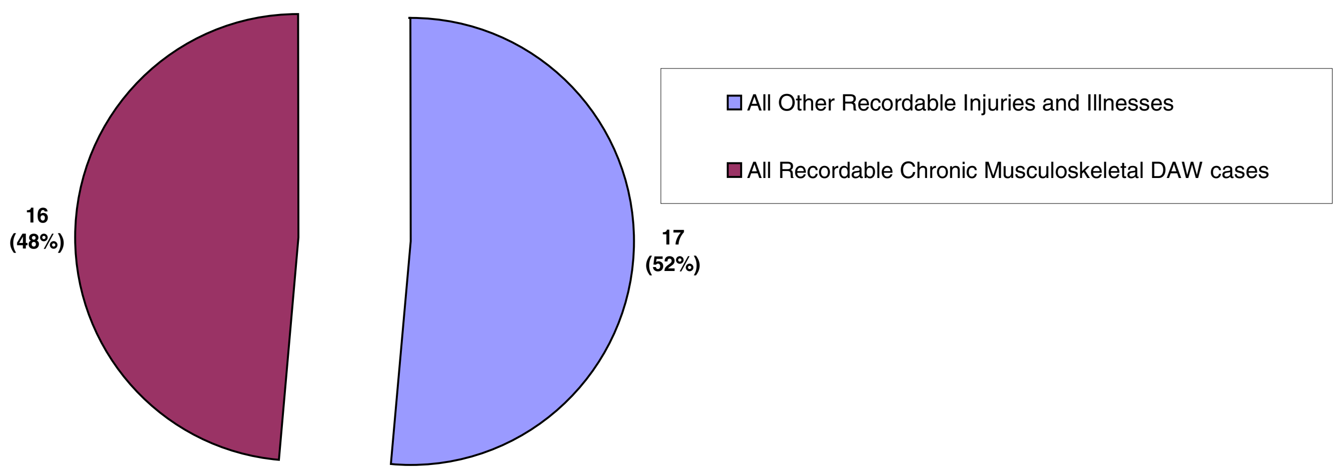


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Figure E-4
Percentage of Musculoskeletal Disorders[1]
Among Production Workers Involving Days Away from Work
Shipyard Five
1995-1998

[1]OSHA 200 Logs

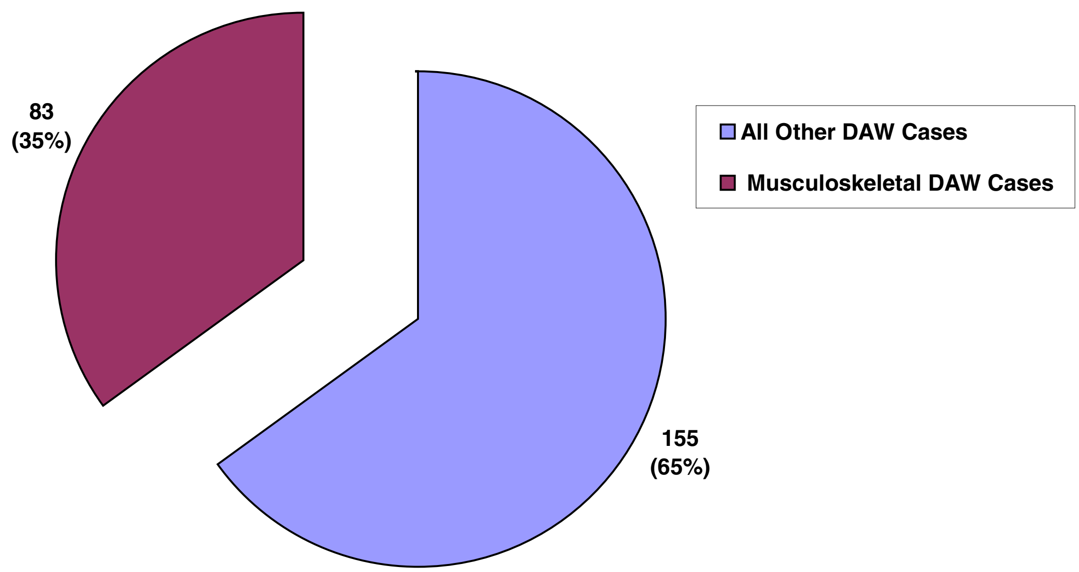

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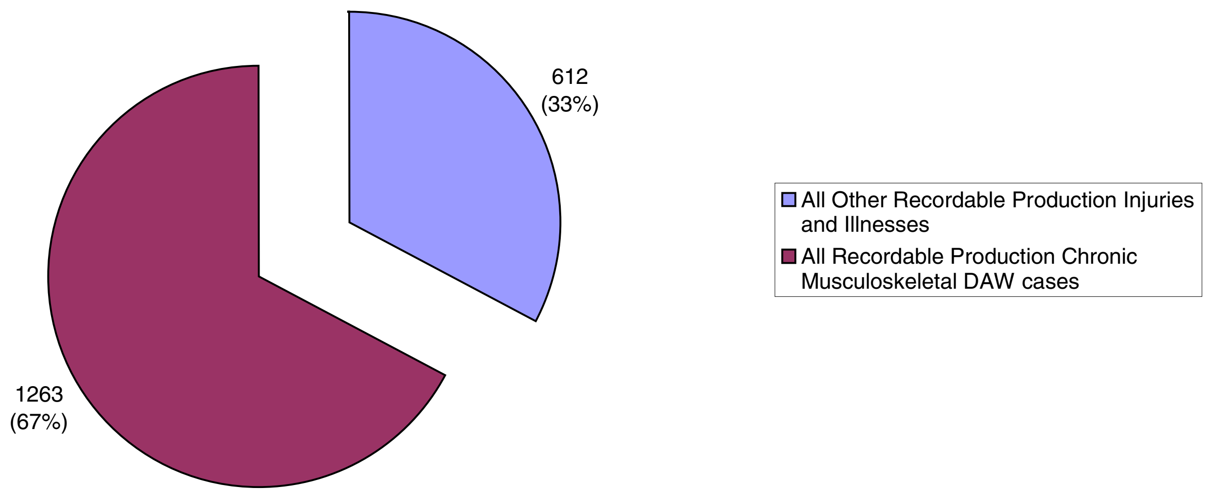
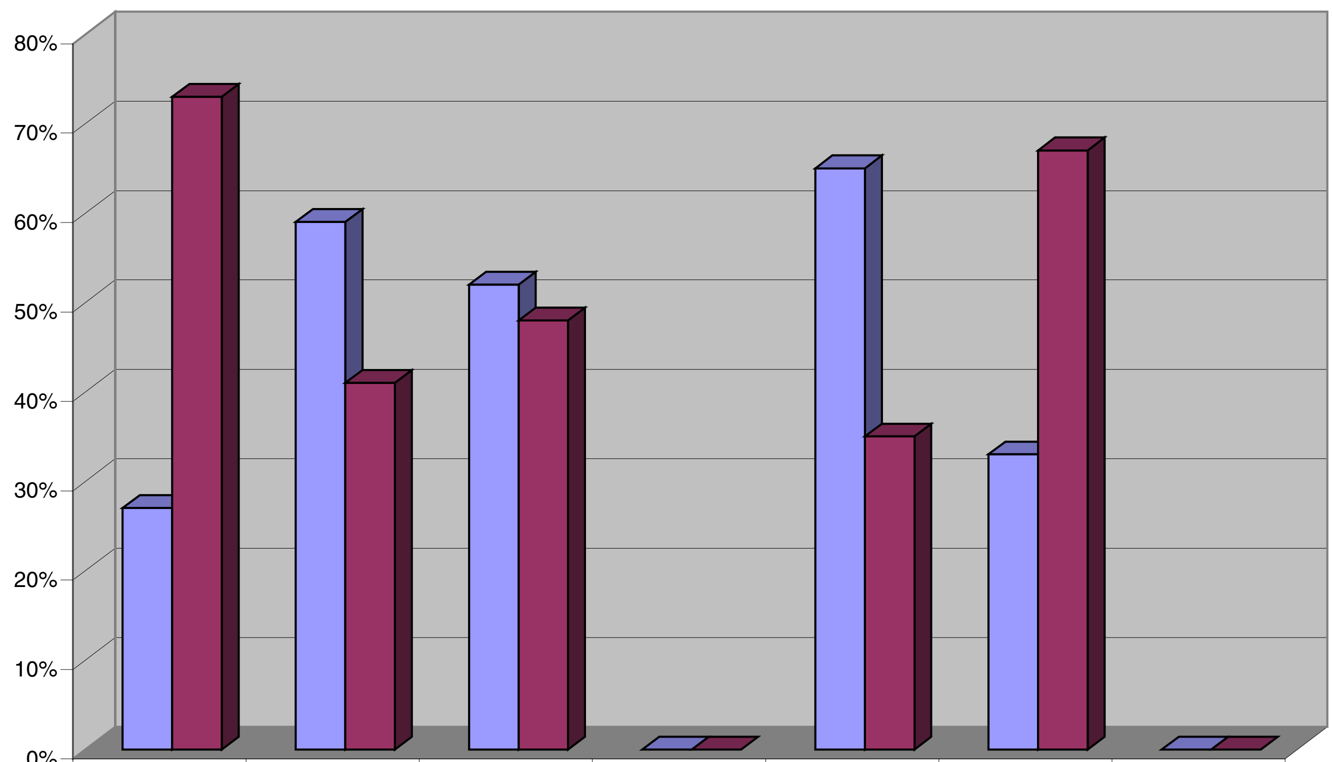
Figure F-4
Percentage of Musculoskeletal Disorders
Among Production Workers Involving Days Away from Work (DAW)
Shipyard Six
1994-1998

[1] OSHA 200 Logs



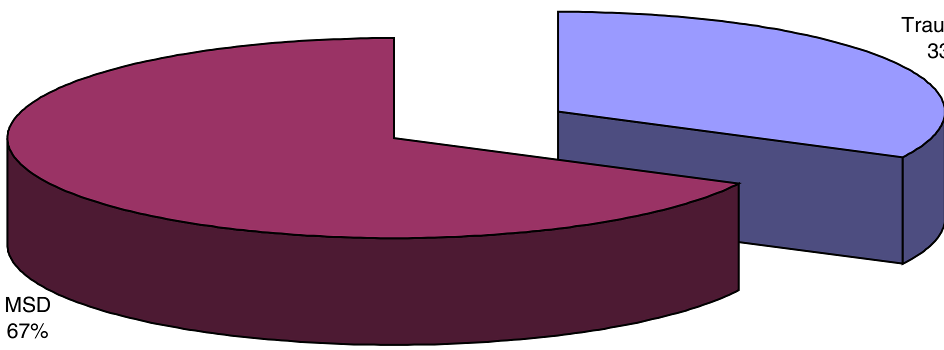
Percent of Musculoskeletal Disorders Among Workers Involving Days Away From Work (DAW) By Shipyard



	Shipyard 1	Shipyard 2	Shipyard 3	Shipyard 4	Shipyard 5	Shipyard 6	Shipyard 7
Traumatic	27%	59%	52%	0%	65%	33%	0%
MSD	73%	41%	48%	0%	35%	67%	0%

Graph above identifies percentage of all lost time injuries and illnesses by traumatic and Non-Traumatic MSD. Shipyard(s) four and seven have not supplied us with data necessary for inclusion into this phase of the analysis.

Overall Percentage of Musculoskeletal Disorders Involving Days Away From Work for All Shipyards Combined



Pie Chart does not include data from Shipyard Four and Seven. Combined analysis reveals that musculoskeletal disorders account for 38 percent of overall injuries/Illnesses and 67 percent of all Injuries/Illnesses resulting in Days Away From Work.

PHASE TWO

JAPAN TRIP REPORT

Japanese Shipyard Ergonomics Trip Report

8/27/98 - 9/3/98

National Institute for Occupational Safety and Health (NIOSH):

James D. McGlothlin, Ph.D., CPE, Research Industrial Hygienist, Engineering Control Technology Branch, Division of Physical Sciences and Engineering

Stephen D. Hudock, Ph.D., CSP, Engineering Control Technology Branch, Division of Physical Sciences and Engineering

Thomas R. Hales, M.D., M.P.H., Medical Officer, Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations, and Field Studies

National Shipbuilding Research Program (NSRP) SP-5 Committee:

Karl V. Siegfried, formerly Ergonomics Coordinator, Bath Iron Works, now with Maine Employers' Mutual Insurance Company

U.S. Navy Office of Naval Research (ONR-Asia):

Jack Garvey, Associate Director, Industrial Technology

Koichi Baba, Director, Maritech Engineering Japan Co., Ltd.

Terry Lyons, M.D., M.P.H., USAF, Office of Scientific Research, Asian Office of Aerospace Research & Development

Hitoshi Narita, Ph.D., Senior Advisor, Science and Technology

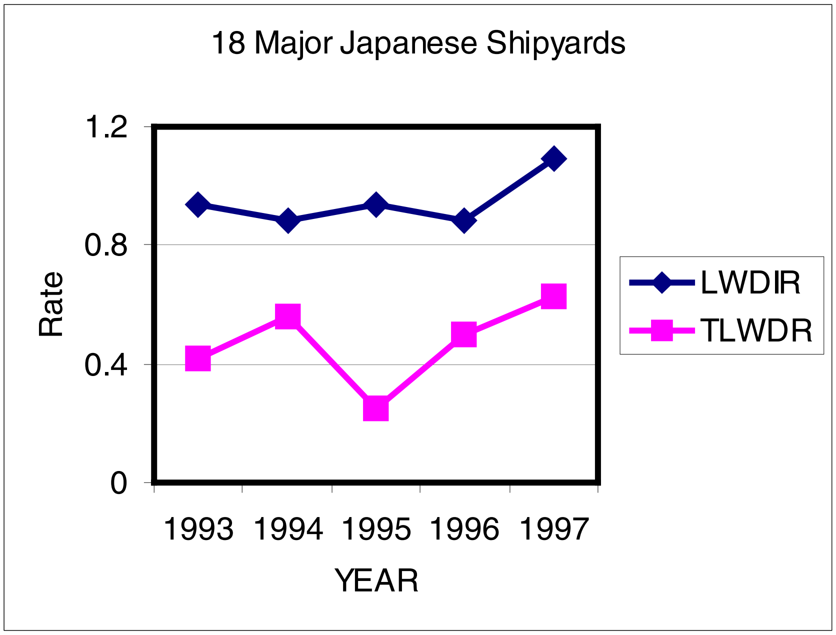
EXECUTIVE SUMMARY

The Japanese shipbuilding industry is considered #1 in the use and development of technology and in production tonnage.

According to Japanese shipyard sources, there are no government subsidies for the Japanese shipbuilding industry. For the six Japanese yards building military surface ships, prior to 1998, contracts were on a cost-plus basis. In 1998, switched to fixed-price contracts. However, military ships are a limited portion of yards' revenue (5-10 %). In U.S., military vessels are 80-90 % of yards' revenue.

In Japan, only have general industry safety regulations, not shipyard-specific standards. Most shipyards surpass government standards with company standards.

Injury data is reported to a trade association (Shipbuilders' Association of Japan, 18 member large to medium shipyards -- based on parent company size), then sent to Ministry of Labor. Only collect traumatic injuries incurred at the workplace and record these. No record is kept of work-related illnesses or those conditions with a multi-factorial etiology, such as low back pain. Injury logs also include subcontractors.



Management assumes all responsibility for employee injuries. It is never operator error, or the employee's fault. No retaliation for employee to bring injury claim to medical offices.

Company-run hospitals for both work-related claims as well as family medicine. Do pre-employment and annual physicals.

No workers compensation system. Injured worker receives 100 % of salary for up to 6 months paid by company.

Newly hired employees receive fourteen personal days per year for vacation or sick leave, increasing to 21 days per year for more senior employees. Subcontractors get personal days, but not paid holidays.

Very low company employee turnover (<1 % per year), while subcontractor employees' turnover rate is much higher (approximately 20 - 30 %)

Training of new company hires is extensive, several months. Subcontractor training may be only hours, assuming their workers already have training and job skills.

Four out of five yards were post-1970. Better layout and facilities.

High company employee to subcontractor ratio. About 50/50. Once job is done can lay off subcontractors without effecting company employees.

Shipbuilding is a small portion of these companies revenues, compared to construction, machinery, etc. Multi-dimensional companies, which can supply themselves with, needed equipment.

Within the company, there appears to be a paradigm shift of safety being equal to productivity, which in turn is equal to quality. Ex. Director of Health & Safety is peer of all other managing directors. Ex. Mandatory safety rotation of two months in safety patrol group for all workers. Ex. Each team reviews each work-related injury for cause and prevention ideas. Ex. Each team has safety meeting each morning as well as for production scheduling, Ex. Each team must come up with improvements for company and posted for all to see (Kaizen)

Uniforms for all within yard, from laborer to General Manager.

Lot of work performed at ground level. Little overhead work observed.

No material or tools being carried from workplace to workplace, indicating limited need for rework and high quality. Good design of workflow and scheduling/planning. Perhaps limited design changes after initial production begins.

PPE problematic. Lack of uniformity for wearing safety glasses, hearing protection, steel-toed shoes and compliance with respirator programs. Nonetheless, very few foreign bodies in eyes. However, fair amount of pneumoconiosis, vibration white finger, hearing loss. However, don't record occupational illnesses or multi-factorial conditions.

Approximately 1 % of workforce had safety-related jobs within production areas. Relatively huge commitment. Safety uniform, green cross on hardhats, armbands, lanyards.

On-board conditions similar to U.S.

Regulations effect top of management practices but don't reach down to production level directly. Macro-level going down the line to yards and production level. Large yards can influence the development of regulations. Government-driven (report but no inspection unless an audit), industry-driven, company-driven. Cost effectiveness can be documented, productivity less so. Safety affects production.

Amount of rework can be indicated by the amount of material being moved to a new position to complete the work. Rework is out-of-position work and may place worker at higher risk of injury and should be considered in-depth before acted upon. Rework is cost-effective for shipyards, but very inefficient due to cost plus contracts. No justifications for rework. Effects bottom line of shipyard profits. Commercial ships minimize rework to be efficient and get ships delivered, fill more orders, build more ships, etc.

Date: August 27, 1998

Shipyard: IHI Tokyo Shipyard (Ishikawajima-Harima Heavy Industries Co., Ltd.)

Location: Tokyo, Japan

Physical Capacities:

Site area: 169,676 m^2 ~ 42 acres

Floor space: 79,142 m^2 ~ 20 acres

No. 1 dock: 421 ft L x 59 ft W x 22 ft D

No. 2 dock: 549 ft L x 73 ft W x 22 ft D

Berth: 564 ft L x 97 ft W

Cranes: 85T, 45T x 3, 10T x 2, 6T, and 5T

Workforce Capacity:

Personnel: Approximately 300 IHI production workers and 400 subcontractors.

Mean age: Approximately 41 years old for IHI. Subcontractors approximately 39.

Work shifts: One shift 8 a.m-12 noon, 1-5 p.m. Up to 10 hours per month mandatory overtime with 33 % premium

Primary product: Small to medium size ships, destroyers including Aegis-class, cargo carriers, passenger ships, car ferries, and special-purpose vessels

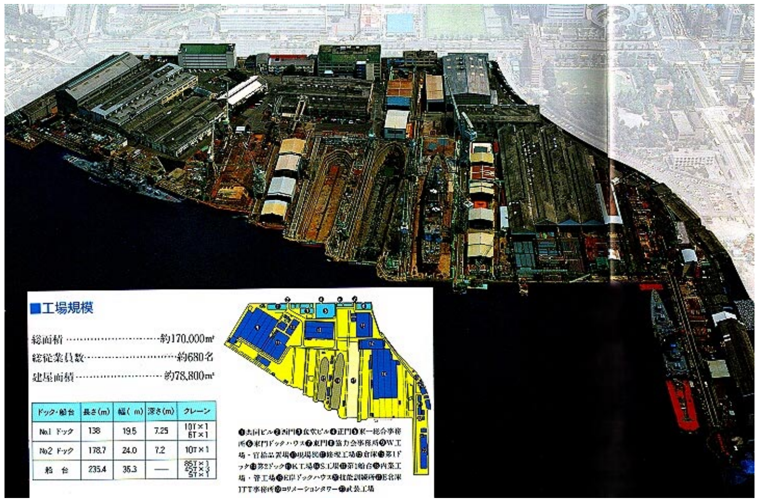
Contacts:

Shigeyuki Tanaka, General Superintendent

Yohji Nishikawa, Manager, Naval and Special Vessel Production Workshop

Kozo Ezaki, General Manager, Sales Business Department

Mr. Kase, Section Manager, Safety and Health



General Observations:

IHI Tokyo shipyard is an urban shipyard with an urban workforce. It produces a mix of commercial and military ships. It is one of 6 companies in Japan eligible to bid on military surface vessels. Japan's first private shipyard (1876).

For an AEGIS-class destroyer, from start of fabrication to keel is 6 months. From keel to launch, 6 months. From launch to final delivery, 2 years. Total production time, 3 years.

Company unions, not trade-specific unions. Negotiate holidays and pay issues but do not normally strike.

Engineering Controls:

For an older yard, good facility layout and product flow from one point of the process to the next, reducing excess handling of raw material.

While plasma cutting, using downdraft ventilation for pulling slag through a water bath to trap particulates for decreased dust in the workplace.

More frequent use of automated equipment than at U.S. shipyards. Use of automatic welding equipment, which results in improved postures, decreased static effort, decreased hazardous fume exposure, and increased amount of weld per person. (See figure below).

Japanese work standards allow for welding over weldable primer unlike U.S. Navy contracts. The removal of weldable primer on U.S. Navy ships requires the increased use of pneumatic tools in awkward hand postures, rework, etc. The Japanese practice of welding over weldable primer results in decreased pneumatic tool use, decreased dust and decreased need for housekeeping, and, therefore, increased efficiencies due to eliminating rework.

Ships are assembled in smaller number of larger blocks or units due to high crane capacity resulting in less, overall handling of blocks. This also allows for the blocks to be within a controlled work environment a longer time before staging into graving dock since it is easier to move material into unit's landside vs. dockside.

The use of automatic cable pullers to run cable throughout the ship results in decreased arm/back stress, and increased time savings in pulling lengths of cable.

Majority of work is performed at ground level. Very little overhead work is performed. Overhead work was addressed via work process design.

Bar coding of small parts and steel plates, so know what part is needed for what block, etc.

Welding leads on jib booms, 3+ sets per boom.

Kobel automatic welding units.

Administrative Controls:

Immediately inside the yard gate is a display of injury data for each section of workers listing foreman's or subcontractor's name giving number of injuries and lost workdays for each section. Serves to inform all employees and subcontractors of safety status within the yard.

Within the company, there appears to be a paradigm shift of safety being equal to productivity, which in turn is equal to quality. Ex. Director of Health & Safety is peer of all other managing directors. Ex. Mandatory safety rotation of two months in safety patrol group for all workers. Ex. Each team reviews each work-related injury for cause and prevention ideas. Ex. Each team has safety meeting each morning as well as for production scheduling, Ex. Each team must come up with improvements for company and posted for all to see.

Daily walkthroughs by management and labor looking to address safety, quality and productivity issues

Various safety banners and slogans throughout the yard.

Good work organization in terms of having needed materials on hand when needed. Ex. Leads on movable welders, 3 units on each boom. Kitting of materials near where job is to be performed. Bar-coded small parts know what material is located at each workstation at all times.

Good housekeeping and overall cleanliness of yard. Reduces debris in yard and chance of foreign objects in eyes and slip/trip hazards.

Pace of work was more even throughout the work shift as compared to US yards.

Use high heat resistant paint not just primer, so can weld directly over paint.

Injury Recordkeeping:

Most common injuries are crushes and pinches, followed by slips/falls.

Injury/illness record is legitimate.

Date: August 28, 1998

Shipyard: Yokosuka Shipyard of SHI (Sumitomo Heavy Industries, Ltd.)

Location: Yokosuka, Japan

Physical Capacities:

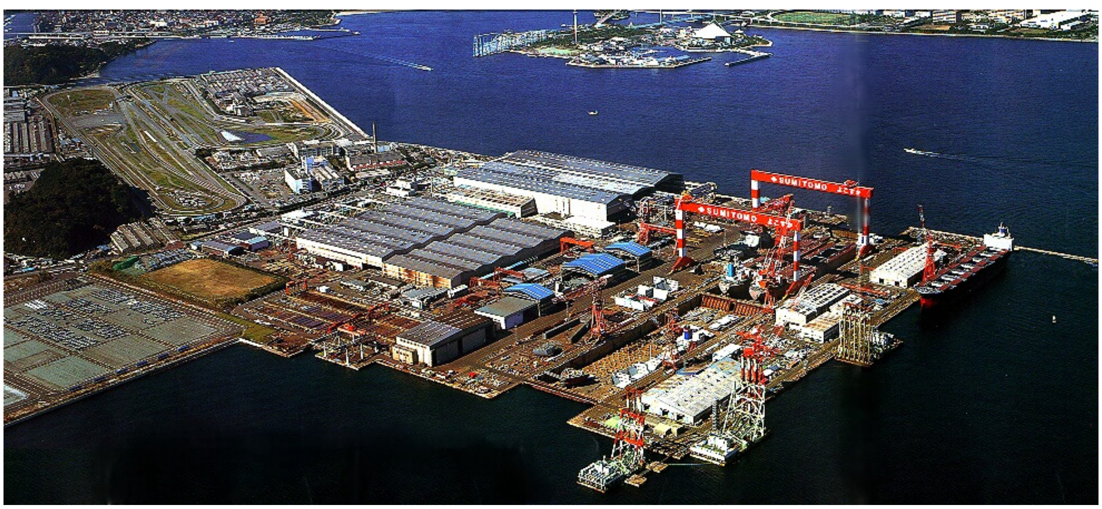
Site area: 550,000 m^2 ~ 136 acres

Floor space: 103,350 m^2 ~ 26 acres

Fitting quay: 2,165 ft LHV

Building dock: 1,840 ft L x 263 ft W x 42 ft D, 500,000 DWT

Cranes: 300T x 2 Goliath (bridge) cranes, 30T x 4



Workforce Capacity:

Personnel: 600 company production workers, 500 subcontractors, and 500 white-collar workers

Gender: No female company production workers. Approximately 1 % subcontractors are Female.

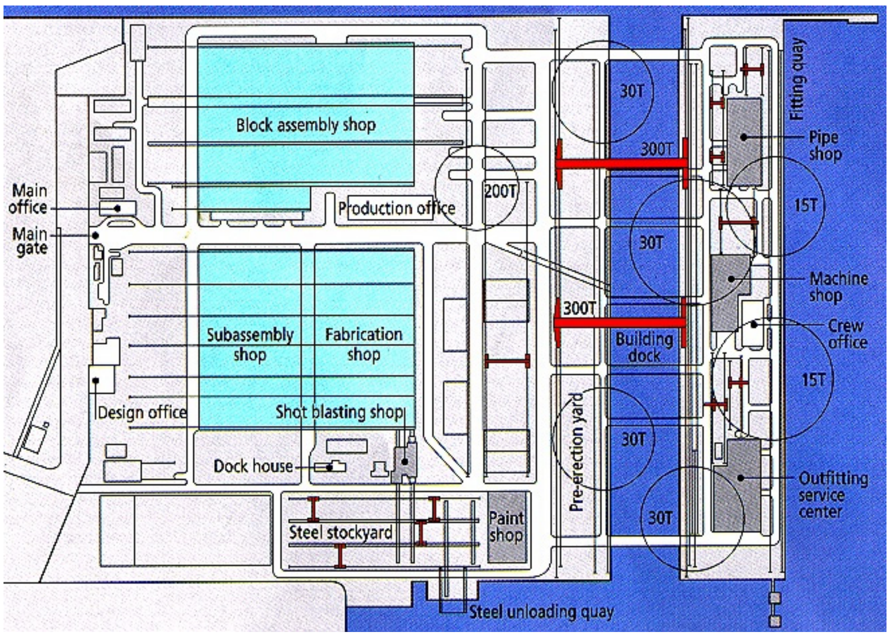
Average age: 40 years

Turnover: Very low within company. Approximately 20 % among subcontractors.

Salary: 150,000 Yen per month plus bonus of 17,000 Yen per month

Work shifts: 1-8 hour shift. Overtime about 15 hours on average with 35 % premium.

Primary product: Double-hull tankers, world's largest tanker, Very Large Cargo Carriers



(VLCC), Panamax bulk carriers.

Contacts:

Shinji Nishimura, General Manager, Construction Dept., Ship and Steel Structure Group

Takeshi Kodama, Section Mgr., Safety and Health

Masaaki Takeuchi, Deputy General Manager

Dr. Koichi Owada, Clinic Physician

General Observations:

Fourteen launches a year. Eighteen months worth of contracts. Yard started 1971. Since then have built over 200 vessels. Facilities layout new and different from older yards. Graving docks for more than one ship at a time instead of building of ways. Sumitomo Yokosuka is a spin off of Uraga shipyard. Urban shipyard as well. On-site research and development organization. Average of only 36 units or blocks per bulk carrier.

Engineering Controls:

Large amount of automatic welding in production process (more than IHI)

Performs more work in buildings - increased production and safety - decreased injuries.

Use of junction box to join cable runs between blocks

Large crane capacity, bigger blocks (2 x 300 T cranes). Team up cranes for doubling up of lifting capacity.

Lacked easy fixes, no lift tables.

No limitations of space. New yard. Worker square footage tremendous.

Flip down welding helmets versus handheld style

On-board environment loss of control after erection. Poor ventilation. Shipside work same as U.S.

Work environment. Cables above walkways on canopy hangers. Good housekeeping. Very few visual obstructions. Good Lighting.

Work practices. No work above waist. Very little re-work. Work design. Work flow. Work pace even. Large amount of work space per individual worker.

No down machinery in need of repair.

Plumbing work laid out on land, modularized construction. Use a lot of flanges/gaskets.

Can pre-assemble and pressure test in the pipe shop before installation on board ship.

Administrative Controls:

Safety organization (4 managers - 8 production level safety staff per department)

Production and designers interact regularly

Safety signs in each work area, hazards locally. Safety monitor patrols. Very similar to IHI. Finger Point to safety concern. Lead by example. Manager awareness of safety. Always thinking of safety and productivity as intertwined or in step.

PPE for welding flash, hand-held mask versus flip-downs. No flash screens around welding areas for nearby workers.

Injury Recordkeeping:

Work restriction assigned for one week then re-evaluated.

Medical clinic. Surveillance. Checkups. Convenience of overall care.

Date: August 28, 1998

Shipyard: Yokuska Ship Repair Facility, U.S. Navy

Location: Yokosuka, Japan

Contacts:

Norikazu Chikuda, Asst. Safety Engineer, Safety Office, US Naval SRF

Mr. Kato, Safety Manager, SRF

General Observations:

Typhoon alert may have been possible disturbance of normal work pattern. Pulling people off of ships during typhoon alert. Normally work is shipboard, not landside. Extraordinary day. Not well organized? May not be representative.

Engineering Controls:

Older machinery age due to nature of repair work.

Welding department was series of mini-cells.

In-line needle gun with anti-vibration damping material made in Japan.

Administrative Controls:

Looked like American yard with Japanese work force.

Difference in managerial style (American vs. Japanese) vs. cultural stereotype of work ethic.

Housekeeping poor.

Big safety department (16 employees).

Tool room looked good

Lack of patrols or vigilance, support for safety.

Work organization poor? Staging of work, New construction vs. Repair

Injury Recordkeeping:

Still had very good safety record.

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Date: August 31, 1998

Shipyard: Tamano Shipyard of MES (Mitsui Engineering and Shipbuilding Co., Ltd.)

Location: Tamano, Japan

Physical Capacities:

Site area: 988,971 m^2 ~ 244 acres

Floor space: 278,072 m^2 ~ 69 acres

Fitting quays: 1175 ft L, 1067 ft L, 792 ft L, 499 ft L, 404 ft L

Building berth 1: 756 ft L x 133 ft W, 120,000 DWT

Building berth 2: 595 ft L x 247 ft W x 35 ft D

Building berth 3: 418 ft L x 47 ft W

Graving dock: 637 ft L x 95 ft W x 30 ft D, 46,000 DWT

Cranes: 150T x 4, 80T x 2, 60T, 20T x 2, 10T x 2, 5T x 2

Workforce Capacity:

Personnel: 1,023 production workers, designers and engineers. 250 subcontractors in shipyard

Primary product: Destroyers, patrol vessels, submarine rescue tender, ocean surveillance ships, tankers, world's most powerful marine diesel engines at 74,640 BHP. Build eight ships a year.

Contacts:

Tadashi Biwa, Director General Manager
Masuo Narita, Deputy Director, General Manager Shipyard
Hiroshi Oyama, General Manager, Ship Construction Dept.
Hisashi Yokouchi, Manager, Co-ordination Group and Safety Group, Ship Construction Dept.
Nobuyoshi Suzuki, Manager, Sales Dept. Tamano Shipyard
Tadashi Yamada, Manager, Safety and Health Section, General Affairs Dept.
Naoto Tagami, Safety and Health Section, Health Dept.

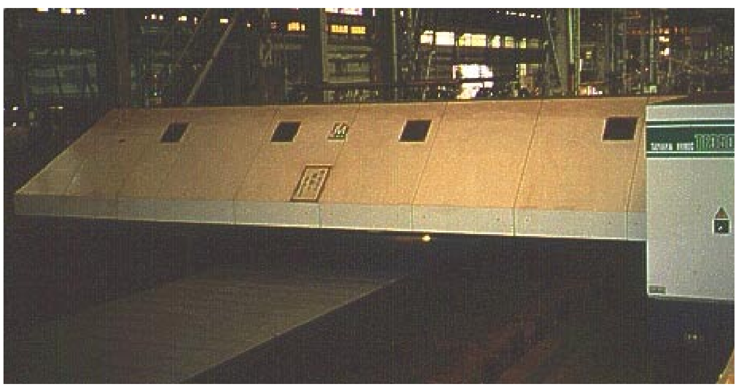
General Observations:

Shipbuilding a growing area within the company. Revenue up, while number of production workers goes down.

Great cooperation due to Dr. Narita's influence.

Engineering Controls:

Power cooling units for blocks are used to prevent employee heat stress



One of first laser cutters in Japan (1993)

Welding leads on jib booms. Other cabling over canopy walkways, not along floors. Significant reduction in trip/fall hazards and increases overall efficiencies when tracing leads.

Plasma cutters ventilated with downdraft to pull particulate down and through bag filter

Use of graving docks Vs building ways – decreases climbing, reduces personal energy expenditure, better posture while on ship since ship decks are level not at an angle forcing workers to lean forward

Automated welding for long runs on tracks.

Vertical automatic welders

No staging (scaffolding) in graving dock. Use cherry pickers and automatic welders. Erection of staging was more dangerous than using staging.

Welding over weldable primer, not like the U.S. Navy specifications

Administrative Controls:

Have OSHA equivalent in Japan, but company regulations are more severe than government regulations, and therefore are not seen as a threat. Government regulations for minimum, shipyards go beyond. Such as safety committees, health screening tests

Countermeasures to reduce accidents campaigns. Booklets on Control Schemes for Safety and Hygiene Campaigns for the year. Safety and Hygiene regulation handbooks. Many handbooks.

Industrial hygiene more active at MES, than at other shipyards

If an accident occurred would investigate and institute countermeasures yard-wide to prevent similar accident from occurring elsewhere..

Monuments are safety awards from the Japan Ministry of Labor in recognition of 20 million and 15.7 million hours worked without a lost day injury

Usability of design Vs producibility of design. Human factors considered for customer. Production planning takes care of worker ergonomics.

Blasting on day shift, painting on night shifts.

Injury Recordkeeping:

Increase of injuries from subcontractors according to SAJ data unexplainable.

Annual screening of workers. Occupational illnesses not recorded as part of logs, as opposed to traumatic injury data.

Cost effectiveness of screening exams was questionable, ex. stomach x-rays. Cosmetic approach is to screen everyone to catch a couple with disease or disorder. Concern over true false positives rate, positive predictive value, and negative predictive value of screening tests. For example, the blood test for organic solvents is very crude and non-specific.

Observing a welder with beard and wearing a respirator around his neck brings into question the effectiveness of respirator program. Also welding overhead. Person carrying material on his shoulder struggling but rare occurrence.

Fifteen years ago had 75 injuries. The Company dedicated itself to reducing injuries.

Responses to written questions from MES:

1. The following operation methods have been adopted to improve the safety, productivity and quality:

A) Decrease of operation at a place having a height of more than 2 meters – federal law,

B) Decrease of operations to set up scaffolding,

C) Decrease of operations in an unnatural posture,

D) Decrease of heavy labor – lifting limit of 30 kg,

E) Decrease of operations in high temperature,

F) Decrease of mixed operations in same place and area,

G) Decrease of crane handling operations, and

H) Decrease of hand welding

2. Improvement of the operations methods, which are effective to safety, concerns:

A) Use of working stage vehicles (cherry pickers) is effective in prevention of danger due to falls,

B) Furnishment of handrails to the end of blocks and the opening is effective in the prevention of danger due to falls,

C) Use of lifting magnet and handling beam is effective in the prevention of danger due to crane and slinging work

3. Examples of improvement of operations which are related to safety/ergonomics in the ship building processes:

A) Enlargement of a block – Decrease of operations inside ship and at a height

B) Increase of block outfitting jobs – Decrease of operations at a height and increase of downward operations

C) Use of working stage vehicles (cherry pickers) – Decrease of operations to set up the scaffolding

D) Handling by roller conveyor, etc. – Decrease of crane and slinging works

E) Furnishment of portable coolers – Decrease of hot works

F) Decrease of mixed operations in same place and area – Controlled by overall operation leader at process meeting at beginning of each shift

G) Installation of automatic welding machines – Decrease of length of time operating in same posture

4. Method related to safety/ergonomics in the design and manufacture of ships:
   A) Use of CAD/CAM for ship's blocks, pipes,
   B) Design of steps and grips in advance for workers to use when dismantling the scaffolding in the ship
5. Information of injury and illness within shipbuilding
   A) Type of accident, which occurs frequently, and workers' trades
      1) Accidents due to falls when operating on portable ladders, vertical ladders, and at openings. Trades: welders, outfitters, etc.
      2) Accidents due to catching or involving a part of the body by the rotating tools, the parts of blocks and others. Trades: Assemblers of blocks, slinging workers, etc. Pinch points
   B) Type of industrial illness, which should be controlled by MES, specific occupations, and number of controlled workers:
      1) Pneumoconiosis – welding – 77 persons (3.0 % of workers)
      2) Hearing loss – grinding and chipping – 197 persons (7.6 % of workers)
      3) White finger disease – grinding and chipping – 10 persons (0.2 % of workers)
      4) Organic solvent poisoning – painting – none
      5) Specified chemical substances poisoning – painting – none
      6) Ionizing radiation – X-ray inspection – none
      7) Asbestos pneumonia – heat insulation – none (not using asbestos at present)

6. We have had risk factors about setting and dismantling scaffolding for long time, but recently MES succeeded in reducing such accidents by the use of

working stage vehicles (cherry pickers) and performing the countermeasures to prevent danger due to falls (safety lines, tying off).

7. Work schedules are prepared as follows:

   A) Line chart of ship building schedule – scheduling in 2 years

   B) Main schedule of ship building process – individual long term schedule of the ship

   C) Medium term schedule of the ship building process – individual schedule of block assembly, outfitting, painting, etc.

   D) Weekly work schedule – including details of operations, workers, work sharing for overtime and holiday work, etc.

   Holidays in a year are decided in advance between company and labor union.

   Workers can take paid holidays, memorial holidays and the refresh holidays.

   There is no incentive system.

8. Main purpose of health control program:

   A) To check the health of workers periodically

      1) Undergoing medical examination every year – physical, chest X-ray, urine test, blood pressure screening, electrocardiogram, blood test

      2) Undergoing a specific medical examination every year for some workers.

         Examination for pneumoconiosis, white finger disease, organic solvent poisoning, specified chemical substances poisoning, hearing loss, ionizing radiation exposure, impairment by VDT, for midnight workers, for hard overtime workers, for new workers,

   B) To prevent the disease caused by their occupations:

1) Wearing personal protective equipment – protective mask, goggles, hearing protectors, etc.

2) Improvement of working environment – ventilation fans, portable coolers, etc.

9. Individual responsibilities concerning safety, productivity and quality:

A) Worker should have responsibility about his performance, actions and results on his operations

B) Foreman should have responsibility as supervisor in the scope of his work

C) Middle manager should have responsibility of management about the result of his work

D) Upper manager should have overall responsibility of management and about the result of his work

10. Safety regulations, safety management programs and safety standards as follows:

A) Safety and health regulation of MES in compliance with governmental laws, rules, and regulations

B) Traffic regulation at Tamano works

C) Safety management program at Tamano works

D) Safety standard such as “Standard of scaffolding,” “Standard of safety cap,” and “honor of a man of safety merit”

Date: September 1, 1998

Shipyard: Mizushima Shipyard of Sanoyas Hishino Meisho Corporation

Location: Mizushima, Japan

Physical Capacities:

Site area: 291,000 m^2 ~ 72 acres

Fitting quays: 1464 ft L, 933 ft L, 903 ft L, 610 ft L

Building berth: 2059 ft L x 192 ft W x 38 ft D, 80,000 GT

Cranes: 240T x 3, 30T, 20T, 10T, and 5T

Worker Capacity:

Personnel: 290 production workers, 350 subcontractors, and 175 office staff

Gender: 2 female SHM employees in production, no female subcontractors

Average age: 39 for all SHM employees, about 32-33 for SHM production workers

Work shift: 1 8-hor shift. Overtime limited to 50 hrs maximum. Average of 30 hours per month with a 35 % pay premium (negotiated).

Primary product: Double-hull tankers, bulk carriers, chemical tankers, and pure car carriers

Contacts:

Kikuo Iwasaki, Deputy Manager, General Affairs Department, Safety and Environment Section Manager

Takao Matsumuru, Safety and Environment Section, General Affairs Department

General Observations:

Called a medium-sized yard, however, classified only according to size of parent company.

About 8 months to complete tanker or bulk carrier. 3 months from pre-fabrication to keel.
2 x 28-day cycles from keel laying to launch. 40 working days from launch to delivery.

Yard in Mizushima built in 1974.

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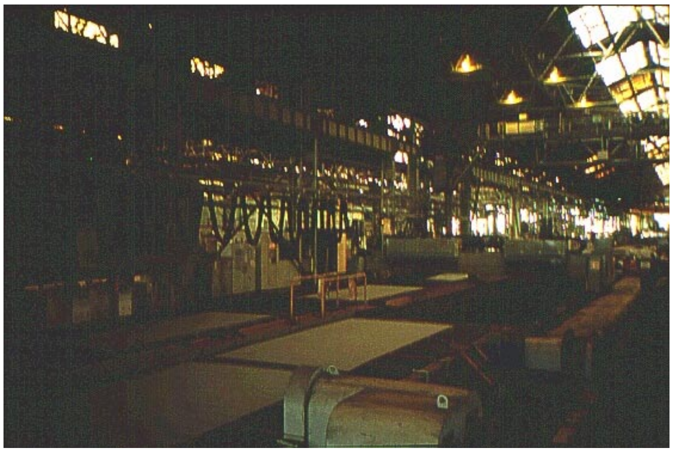
Engineering Controls:

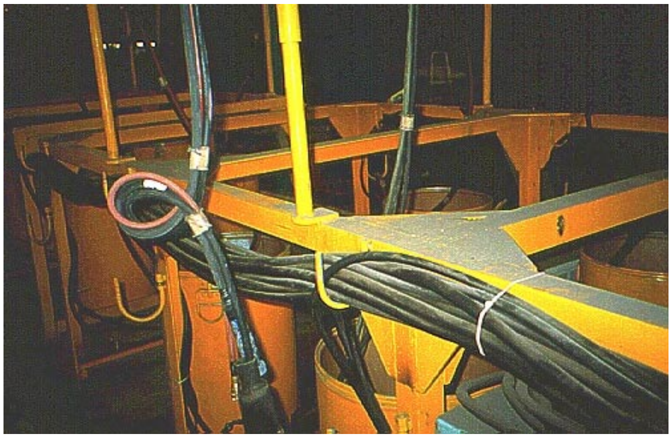


Large work areas, open spaces.

Automatic <u>robotic</u> welding machines, at least 2. Fully computerized. Can weld both sides at once. Box shapes, different heights. Not just long stretches. Automatic robotic, automatic, semi-automatic welding.

Square paint can 20 kilograms, significantly less than US material.

Weld directly over paint, not just primer

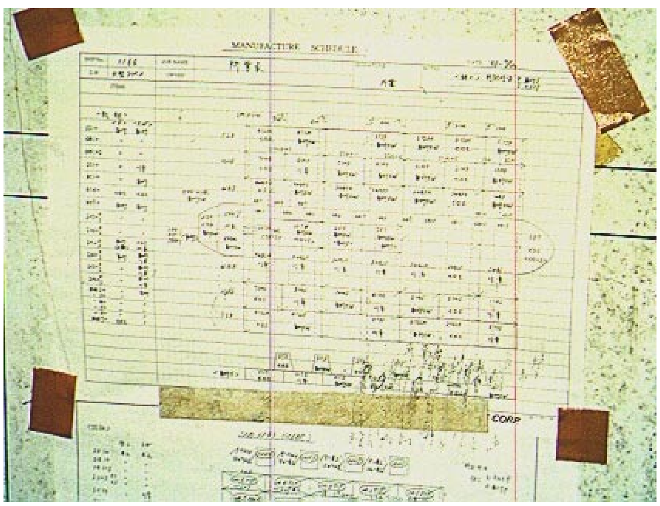


Orange barrels for coiled leads was employee idea. Recycled barrels. Keeps leads off the floor.

Shipboard environment in Japan equal to or more congested to that in the US. Maybe even more hazardous than in US.

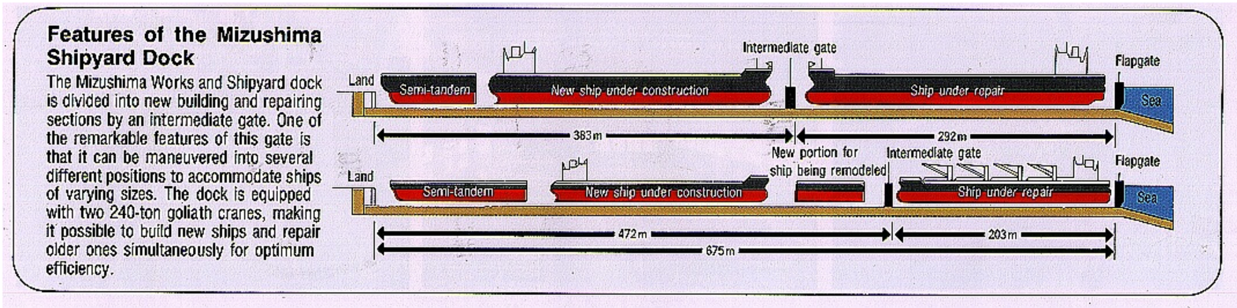
Cherry pickers staging and scheduling. Guard on cherry pickers due to crush injury.

Put nets up over outside work to reduce heat and sun environmental load.



Crane scheduling day in advance like clockwork. Can tell if behind for day if crane is idle. Workers rig normally small jobs.

Housekeeping dockside is very good. Leads coiled.



Semi-tandem construction in graving yard. Can work on more ships at a time than building on ways.

Transfer of material for workflow minimized. Not carrying around tools. Lack of rework.

Elevator at graving dock to get topside of ship

Element of planning to combine units or blocks are right at intersection or seam of pieces or units. Transition areas before assembling units into bigger blocks.

Administrative Controls:

First of the month inspection teams, 2 hour tour, 3 groups of twelve with management and labor. Common in all yards. Monthly general shipyard meeting from general manager to all workers.

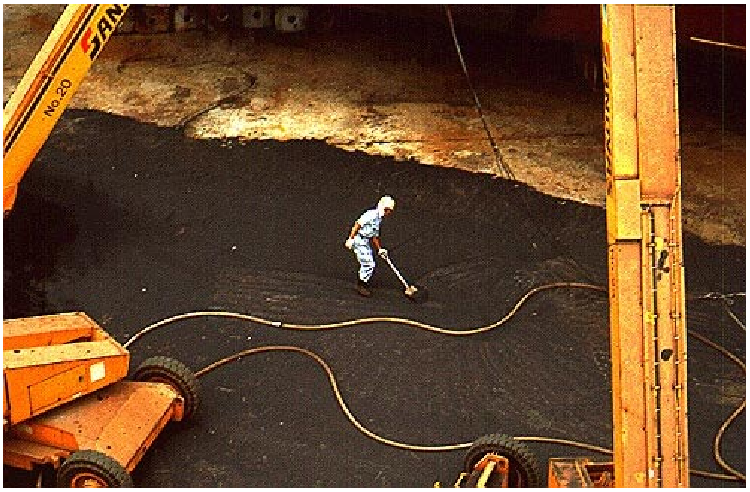
Once a year industrial hygiene school (voluntary) after hours.

Used to reward safety ideas.

Use regular work team to fill in for vacation and sick days. Cross-train workers to fill in for different workers being out.

Train, educate and explain why things are done to new employees.

Safety has top management commitment. Good hygiene.



Lack of respirator use for carbon based abrasive agent cleanup in graving dock (Black Beauty)

Guide for responsibility and authority of safety and health for each level of supervisor.

Injury Recordkeeping:

In the United States, a State OSHA may have jurisdiction on land, Federal OSHA, Coast Guard, and Longshoreman's Act, once a ship is in the water. Limited general industry regulation in Japan.
Four primary safety and health issues: VDT, vibration, hydrocarbons and silicosis. Solutions not very sophisticated. Microbreaks for VDT. Vibration rubber damping and gloves which are voluntary. Concern over the health care screening validity of some testing. Perhaps overly protective. Injury logs appears accurate, but don't track occupational illnesses.

Specific questions and answers:

1. How is safety/ergonomics incorporated into the shipbuilding and repair processes?
   – Providing a good work environment and easy work procedures makes for a safer workplace.
2. Are there specific examples of how simple solutions to safety concerns have been addressed at the facility?
   – Using cherry picker crush cage is strictly enforced. In place due to a fatality.
   – If there is an injury, an improvement is made to prevent it from happening again.
   – Automatic stop system on cherry picker. Equipment is modified on-site to add safety features.
   – Tool suppliers are flexible and can modify tools on request.

3. Are there specific examples of how safety/ergonomics is incorporated into the shipbuilding and repair processes?
   – The use of cherry pickers and shade nets.

4. Are there specific examples of how safety/ergonomics is incorporated into the design and manufacture of ships?
   – Have the design department design for "palms-down" work. If the unit is to get flipped, build in as much as possible early in a "palms-down" position before flipping the unit.
   – Work on board ship as little as possible.

5. Is injury and occupational illness information available as it relates to safety programs with respect to specific trades or occupations within shipbuilding and repair?

– Occupational medicine physician attends monthly meeting and addresses a topic
such as hearing loss, VDT work, exposure to vibration or hydrocarbons.

6. Have specific occupational risk factors been identified for specific trades or occupations within ship building and repair?
– Occupational risk factors not tracked by trade

7. What are the work schedules at each facility, such as incentive systems, overtime, extended workweeks and vacation scheduling with respect to production cycles?
– No incentive system
– Overtime limited to 50 hrs per month. Average is 30 hrs per month. Overtime paid
a union-negotiated 35 percent bonus, Federal minimum is 25 percent.
– Work one shift from 8 a.m. - 12 noon, 1 hr lunch, work 1 p.m. - 5 p.m.

8. What are the characteristics of the workers' health care programs at each facility?
– Have occupational medicine physician at nearby clinic.

9. What are the individual responsibilities of workers, middle management and upper management concerning safety, productivity and quality during ship construction and repair?
– Each level has guidelines for safety concerns

10. Are there safety guidelines, programs or regulations, which are followed by the ship
building and repair facilities?
– Company has handbooks for safety for new hires.

Date: September 3, 1998

Shipyard: Koyagi Plant, Nagasaki Shipyard and Machinery Works of Mitsubishi Heavy Industries, Ltd.

Location: Nagasaki, Japan

Physical Capacities:

Site area: 1,503,893 m^2 ~ 372 acres

Floor space: 421,801 m^2 ~ 104 acres

Fitting quays: 2083 ft L, 2083 ft L, 1129 ft L

Building dry dock 1: 3020 ft L x 305 ft W, 1,000,000 DWT

Building dry dock 2: 580 ft L x 74 ft W, 20,000 DWT

Repair dry dock: 1220 ft L x 305 ft W, 500,000 DWT

Cranes: 600T x 2, misc.

■香焼工場 Koyagi Plant (敷地面積 site area: 1,503,893m^2)

Workforce Capacity:

Personnel: 2,040 production workers, designers and engineers. 2,000 employees in shipyard area + more in smaller yards. Total less than 2,800. Employment ratio is 70 % MHI/ 30 % subcontractor. Injuries 50 %/ 50 %. IHI employs less workers and more subcontractors.

Average Age: Workforce older than at other yards ~ 45 years for MHI employees, 47-48 years for subcontractors.

Turnover rate: Subcontractor turnover of 30 %. MHI turnover of < 1 %.

Pay scale: MHI pays very well for this area with high wages and bonuses. Workers paid on longevity and skill evaluation, not by trades. No one trade any more important than the other.

Training: 6-month training period for new MHI hires, 2 hours for subcontractors. Same with most yards.

Leave: 20 days for personal use including holidays and sick leave. Real sick days beyond that is leave without pay.

Primary product: Double-hull tankers, LNG carriers, LPG carriers, bulk carriers, floating crude oil storage and production facilities, escort ships, high-speed rescue ships

Contacts:

Akira Tominaga, General Manager, Nagasaki Shipyard and Machinery Works
Kenichi Takasaki, Manager, Labor Administration Department
Shohzaburoh Suzaki, Deputy Manager, Labor Administration Department
Toyoji Taniguchi, Deputy Manager, Koyagi Construction Department
Keiichi Yamaguchi, Section Manager, Safety and Hygiene, Labor Administration Department
Norio Takeo, Section Manager, Ship Repair Shop, Ship Repair Department
Yosihide Harada, Medical Superintendent

General Observations:

1.2 million m^2 is a big yard.

Engineering Controls:

Highest level of automation. Develop new automation where needed to eliminate personnel interaction with raw material. High frequency laser plate bending with water cooling - new machine. Also IHI is developing.

Five section hydraulic ram, remote control joystick operated. Faster to lower blocks onto transporters. Reduces falling. Easier for worker access. Can lower overhead work to shoulder level.

Extremely high crane capacity, 2 x 600 T bridge cranes = 1200 T blocks

Few people, large spaces, less congestion

Little rework results in not carrying equipment from place to place

Low little transporter for sheets of steel

Graving dock can be sectioned both longitudinally and laterally. Can connect stern section to midships. Float stern into place using temporary bulkheads. Aft section more complicated to build so start earlier.

Plates on conveyors start much earlier straight from supply yard.

Elevator to topside

Administrative Controls:

2-meter restriction for falls not for above shoulder work.

1 safety person in each section is unique. Works for them.

Good housekeeping results in keeping dust levels low, eliminating eye hazards.

Housekeeping assigned at 1 hr/week plus at end of each work shift there is cleanup of work areas.

Prep work prior to painting done by subcontractors

Enactment of Safety Crisis Policies in 1995. Showed impact of top management concerns

Training different MHI vs. subcontractors. Subcontractors fixed price may result in less training

General Manager response -- size, diversity, speed of delivery

Injury Recordkeeping:

Back pain is either occupational or non-occupational disease but rarely attributed to workplace in Japan. Therefore not recordable as non-occupational and injury/illness rates lower without them.

Few eye injuries due to designing out the grinding of the primer or automated welders.
Wear goggles when required.

No workers compensation claims because no workers compensation system

Accidents are supervisors fault, not operator error. Not unique in Japan.
Company's community reputation suffers.

APPENDIX A

PRE-INTERVENTION QUALITATIVE

ERGONOMIC HAZARD ANALYSIS

ANGLE IRON POSITIONING

SHEAR PRESS OPERATION

PRELIMINARY SURVEY REPORT:

PRE-INTERVENTION QUANTITATIVE RISK FACTOR ANALYSIS

FOR SHIP CONSTRUCTION PROCESSES

REPORT WRITTEN BY:
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Steven J. Wurzelbacher, M.S.

REPORT DATE:
February 7, 2000

Edited by Karl V Siegfried for NSRP Project Report
July 19,2000

REPORT NO. 229-12a

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ABSTRACT

A pre-intervention quantitative risk factor analysis was performed at various shops and locations within Shipyards as a method to identify and quantify risk factors that workers may be exposed to in the course of their normal work duties. This survey was conducted as part of a larger project, funded through Maritech Advanced Shipbuilding Enterprise and the U.S. Navy, to develop projects to enhance the commercial viability of domestic shipyards. This report is a compilation of multiple reports written and submitted by NIOSH for the MARITECH Project as part of the Pre-Intervention Qualitative Analysis Reports. The application of exposure assessment techniques provided a quantitative analysis of the risk factors associated with the individual tasks. Possible engineering interventions to address these risk factors for each task are briefly discussed.

A1. INTRODUCTION

A1.1 BACKGROUND FOR CONTROL TECHNOLOGY STUDIES

The National Institute for Occupational Safety and Health (NIOSH) is the primary Federal agency in occupational safety and health research. Located in the Department of Health and Human Services, it was established by the Occupational Safety and Health Act of 1970. This legislation mandated NIOSH to conduct a number of research and education programs separate from the standard setting and enforcement functions carried out by the Occupational Safety and

Health Administration (OSHA) in the Department of Labor. An important area of NIOSH research deals with methods for controlling occupational exposures to potential chemical and physical hazards. The Engineering Control Technology Branch (ECTB) of the Division of Physical Sciences and Engineering has been given the lead within NIOSH to study the engineering aspects of health hazard prevention and control.

Since 1976, ECTB has conducted a number of assessments of health hazard control technology on the basis of industry, common industrial process, or specific control techniques. Examples of the completed studies include the foundry industry; various chemical manufacturing or processing operations; spray painting; and the recirculation of exhaust air. The objective of each of these studies has been to document and evaluate effective control techniques for potential health hazards in the industry or process of interest, and to create a more general awareness of the need for or availability of an effective system of hazard control measures.

These studies involve a number of steps or phases. Initially, a series of walk-through surveys is conducted to select plants or processes with effective and potentially transferable control concepts or techniques. Next, in-depth surveys are conducted to determine both the control parameters and the effectiveness of these controls. The reports from these in-depth surveys are then used as a basis for preparing technical reports and journal articles on effective hazard control measures. Ultimately, the information from these research activities builds the database of publicly available information on hazard control techniques for use by health professionals who are responsible for preventing occupational illness and injury.

A2. BACKGROUND FOR THIS STUDY

The domestic ship building, ship repair, and ship recycling industries have historically had much higher injury/illness incidence rates than those of general industry, manufacturing, or construction. For 1998, the last year available, the Bureau of Labor Statistics reported that shipbuilding and repair (SIC 3731) had a recordable injury/illness incidence rate of 22.4 per 100 full-time employees (FTE), up from 21.4 in 1997. By contrast, in 1998, the manufacturing sector reported a rate of 9.7 per 100 FTE, construction reported a rate of 8.8 per 100 FTE, and all industries reported a rate of 6.7 injuries/illnesses per 100 FTE. When considering only lost workday cases, for 1998, shipbuilding and repair had an incidence rate of 11.5 per 100 FTE, compared to manufacturing at 4.7, construction at 4.0, and all industries at 3.1 lost workday injuries/illnesses per 100 FTE.

When comparing shipbuilding and repairing to the manufacturing sector for injuries and illnesses to specific parts of the body resulting in days away from work, for the year 1997, shipbuilding is significantly higher in a number of instances. For injuries and illnesses to the trunk including the back and shoulder, shipbuilding reported an incidence rate of 207.7 cases per 10,000 FTE, compared to manufacturing at 82.1 cases. For injuries and illnesses solely to the back, shipbuilding reported 111.1 cases per 10,000 FTE, compared to manufacturing's incidence rate of 52.2 cases. For the lower extremity, shipbuilding reported 145.0 cases per 10,000 FTE compared to manufacturing at 40.8 cases. For upper extremity injuries and illnesses, shipbuilding reported an incidence rate of 92.2 cases per 10,000 FTE while manufacturing reported 73.4 cases.

When comparing shipbuilding and repairing to the manufacturing sector for injuries and illnesses resulting in days away from work, for the year 1997, by nature of injury, shipbuilding is significantly higher in a number of categories. For sprains and strains, shipbuilding reported an incidence rate of 237.9 cases per 10,000 FTE, compared to manufacturing's incidence rate of 91.0 cases. For fractures, shipbuilding reported 41.7 cases per 10,000 FTE, compared to manufacturing at 15.8 cases. For bruises, shipbuilding reported 61.3 cases per 10,000 FTE, compared to manufacturing at 21.5 cases. The median number of days away from work for shipbuilding and repairing is 12 days, compared to manufacturing and private industry's median of 5 days.

Beginning in 1995 the National Shipbuilding Research Program began funding a project looking at the implementation of ergonomic interventions at a domestic shipyard as a way to reduce Workers Compensation costs and to improve productivity for targeted processes. That project came to the attention of the Maritime Advisory Committee for Occupational Safety and Health (MACOSH), a standing advisory committee to the Occupational Safety and Health Administration (OSHA). The National Institute for Occupational Safety and Health (NIOSH) began an internally funded project in 1997 looking at ergonomic interventions in new ship construction facilities. In 1998, the U.S. Navy decided to fund a number of research projects looking to improve the commercial viability of domestic shipyards, including projects developing ergonomic interventions for various shipyard tasks or processes. Project personnel within NIOSH successfully competed in the project selection process. The Institute currently receives external project funding from the U.S. Navy through an organization called Maritech Advanced Shipbuilding Enterprise, a consortium of major domestic shipyards.

Shipyards participating in this project will receive an analysis of their injury/illness data, will have at least one ergonomic intervention implemented at their facility, and will have access to a website documenting ergonomic solutions found throughout the domestic maritime industries. The implementation of ergonomic interventions in other industries has resulted in decreases in Workers Compensation costs, and increases in productivity.

Researchers will identify seven participating shipyards and analyze individual shipyard recordable injury/illness databases by the end of November 1999. Ergonomic interventions will be implemented in each of the shipyards by the end of June 2000. Intervention follow-up analysis will be completed by the end of December 2000. A series of meetings and a workshop to document the ergonomic intervention program will be held by the end of March 2001.

A3. METHODOLOGY

A variety of exposure assessment techniques were implemented where deemed appropriate to the job task being analyzed. The techniques used for analysis include: 1) the Rapid Upper Limb Assessment (RULA); 2) the Strain Index; 3) a University of Michigan Checklist for Upper Extremity Cumulative Trauma Disorders; 4) the OVAKO Work Analysis System (OWAS); 5) a Hazard Evaluation Checklist for Lifting, Carrying, Pushing, or

Pulling; 6) the NIOSH Lifting Equation; 7) the University of Michigan 3D Static Strength Prediction Model; and 8) the PLIBEL method.

The Rapid Upper Limb Assessment (RULA) (McAtamney and Corlett, 1993) is a survey method developed to assess the exposure of workers to risk factors associated with work-related upper limb disorders. On using RULA, the investigator identifies the posture of the upper and lower arm, neck, trunk and legs. Considering muscle use and the force or load involved, the investigator identifies intermediate scores, which are cross-tabulated to determine the final RULA score. This final score identifies the level of action recommended to address the job task under consideration.

The Strain Index (Moore and Garg, 1995) provides a semi-quantitative job analysis methodology that appears to accurately identify jobs associated with distal upper extremity disorders versus other jobs. The Strain Index is based on ratings of: intensity of exertion, duration of exertion, efforts per minute, hand and wrist posture, speed of work, and duration per day. Each of these ratings is translated into a multiplier. These multipliers are combined to create a single Strain Index score.

The University of Michigan Checklist for Upper Extremity Cumulative Trauma Disorders (Lifshitz and Armstrong, 1986) allows the investigator to survey a job task with regard to the physical stress and the forces involved, the upper limb posture, the suitability of the workstation and tools used, and the repetitiveness of a job task. Negative answers are indicative of conditions that are associated with the development of cumulative trauma disorders.

The OVAKO Work Analysis System (OWAS) (Louhevaara and Suurnäkki, 1992) was developed to assess the quality of postures taken in relation to manual materials handling tasks. Workers are observed repeatedly over the course of the day and postures and forces involved are documented. Work postures and forces involved are cross-tabulated to determine an action category, which recommends if, or when, corrective measures should be taken.

The NIOSH Hazard Evaluation Checklist for Lifting, Carrying, Pushing, or Pulling (Waters and Putz-Anderson, 1996) is an example of a simple checklist that can be used as a screening tool to provide a quick determination as to whether or not a particular job task is comprised of conditions that place the worker at risk of developing low back pain.

The NIOSH Lifting Equation (Waters et al, 1993) provides an empirical method to compute the recommended weight limit for manual lifting tasks. The revised equation provides methods for evaluating asymmetrical lifting tasks and less than optimal hand to object coupling. The equation allows the evaluation of a greater range of work duration's and lifting frequencies. The equation also accommodates the analysis of multiple lifting tasks. The Lifting Index, the ratio of load lifted to the recommended weight limit, provides a simple means to compare different lifting tasks.

The University of Michigan 3D Static Strength Prediction Program (University of Michigan, 1997) is a useful job design and evaluation tool for the analysis of slow movements used in heavy materials handling tasks. Such tasks can best be analyzed by describing the activity as a sequence of static postures. The program provides graphical representation of the worker postures and the materials handling task. Program output includes the estimated compression on the L5/S1 vertebral disc and the percentage of population capable of the task with respect to limits at the elbow, shoulder, torso, hip, knee and ankle.

The PLIBEL method (Kemmlert, 1995) is a checklist method that links questions concerning awkward work postures, work movements, design of tools and the workplace to specific body regions. In addition, any stressful environmental or organizational conditions should be noted. In general, the PLIBEL method was designed as a standardized and practical assessment tool for the evaluation of ergonomic conditions in the workplace.

Two specific processes were identified for further analysis. These processes were: angle iron positioning by a gator bar worker in the steelyard and a shear press operation. Each of these processes is examined in greater detail below.

A4. QUALITATIVE ANALYSIS REPORTS

A4.1 Angle Iron Positioning by Gator Bar Worker in Steelyard

A4.1.2 Process

Prior to use in any sub-assembly, the raw steel stock must be blasted to remove rust of other residual material on the surface of the steel. Angle irons are delivered to the spraying platform in bundles by a mobile crane. The angle irons are dropped onto the platform and are then positioned across the platform as necessary by the gator bar worker and helper.

Figures 3-6 below depict angle irons being adjusted into place by the gator bar worker using their hands or gator pry bar to grip the angle irons.

Figure 4. Gator Bar Worker Positioning Angle Iron & Figure 5. Gator Bar Worker Flipping Angle Iron from Side with Gator Bar

Figure 6. Gator Bar Worker Flipping Angle Iron from End with Gator Bar

A4.1.3 Ergonomic Risk Factors for Gator Bar Worker in Steelyard

While positioning and flipping angle irons for abrasive blasting, the gator bar worker experiences a number of ergonomic risk factors. These risk factors include awkward postures such as extreme lumbar flexion, as well as excessive loads to low back and shoulders.

A4.1.4 Ergonomic Analysis of Gator Bar Workers in Steelyard

Using several of the exposure assessment tools outlined above, an ergonomic analysis was performed for the gator bar worker positioning and flipping angle irons. A Rapid Upper Limb Assessment was conducted for the gator bar worker and the angle separation task (A8.1, Table 1). Analyses of four sub-tasks with unique postures and a composite task analysis each resulted in a rating to "investigate and change immediately."

A Strain Index analysis was performed for the gator bar worker (A8.1, Table 2) with the following results:

1) The Intensity of Exertion was rated as "Somewhat Hard" and given a multiplier score of 3 on a scale of 1 to 13
2) The Duration of the task was rated as 10 - 29 % of the task cycle, resulting in a multiplier of 1.0 on a scale of 0.5 to 3.0
3) The Efforts per Minute were noted to be between 9 and 14, resulting in a multiplier of 1.5 on a scale of 0.5 to 3.0
4) The Hand/Wrist posture was rated as "Bad," resulting in a multiplier of 2.0 on a scale of 1.0 to 3.0
5) The Speed of Work was rated as "Normal," resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
6) The Duration of Task per Day was rated to be between 1 and 2 hours, resulting in a multiplier of 0.50 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 4.5. An SI score less than 5 is correlated to an incidence rate of about 2 distal upper extremity injuries per 100 FTE. Regardless of actual incidence rate, the Strain Index indicates that this task puts the worker at a slightly increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the gator bar worker task (A8.1, Table 3), of the 21 possible responses, fourteen were negative and seven were positive. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the gator bar worker task (A8.1, Table 4), corrective measures were suggested for a number of specific sub-tasks including: grasping the angle iron with the gator bar and using the gator bar to flip the angle iron.

The PLIBEL checklist for the gator bar worker task (A8.1, Table 5) reports a high percentage (~ 80 %) of risk factors present for the elbows, forearms, and hands, and a moderate percentage (~ 50 %) of risk factors present for the neck, shoulder, upper back, and lower back. Several environmental and organizational modifying factors are present as well.

A4.2 Shear Press Operator

Figure 7 Shear Press Operator Placing Steel Plate on Shear

A4.2.1 Process

Figure 8. Shear Press Operator Hooking Small Cut Pieces

The primary process for the shear press operator is to cut steel plate to various dimensions as required for hulls and subassemblies. The particular process flow for the shear press is as follows:

1) Raw plates are moved from pallets to the shear by jib crane that sits between stations

2) Long plates are laid across an array of roller bearing supports to hold weight of plate while being sheared, and

3) Cut plates are dropped at the back of the shear onto a sloped tray that reaches to ground level. Smaller pieces may not slide to the bottom of the tray and must be hooked and slid to the bottom by the shear press operator,

4) Cut plates are either manually lifted or lifted by jib crane and placed into containers.

Shear Press Operator Lifting Pieces at Back of Shear

Shear Press Operator Using Jib Crane to Lift Cut Plate

A4.2.2 Ergonomic Risk Factors of Shear Press Operator

Shear press operators often lift awkward loads from the ground-level shear chutes and material supply pallets. Contact stresses experienced by the shear press operator include kneeling on the floor to get material and contact with the sharp edges of the raw or cut material.

A4.2.3 Ergonomic Analysis of Shear Press Operator

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the shear press operator task (A8.2, Table 6), of the 21 possible responses, seven were negative, seven were positive, and seven were not applicable. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

The NIOSH checklist for manual materials handling consists of 14 items. When applied to the shear press operator task (A8.2, Table 7), five responses were positive and nine negative. In this checklist, positive responses are indicative of conditions that pose a risk to the worker of developing low back pain. The higher the percentage of positive response, the greater the risk of low back pain.

The NIOSH Lifting Equation was used to analyze the sub-task of manually picking material up from the back of the shear press. The analysis (A8.2, Table 8) for this task suggests a recommended weight limit of 12.4 pounds, given the assumed posture. Given that the typical weight of the plate is about 20 pounds, it is determined that 92 % of the male population and 41 % of the female population can perform this task without an increased risk of low back pain.

The University of Michigan 3D Static Strength Prediction Program was used to analyze the shear press operator lifting a plate one-handed from the back of the shear machine (A8.2, Table 9). Analysis of this sub-task resulted in an estimated disc compression loads at the L5/S1 disc to be 673 pounds, below the NIOSH Recommended Compression Limit of 770 pounds.

The PLIBEL checklist for the shear press operator task (A8.2, Table 10) reports a moderate percentage (between 40 and 50 %) of risk factors present for the neck, shoulder, upper back, and lower back. Several environmental and organizational modifying factors are present as well.

A5. CONTROL TECHNOLOGY

Possible interventions and control technologies are mentioned briefly here. A more detailed report of possible interventions is in press.

A5.1 Angle Iron Unload in Steelyard Possible Interventions

Changes in how the load is slung and/or handled by the crane may help in distributing the angle iron across the platform. A simple push mechanism on the unloading platform may eliminate the need for two workers to hook and pull long angle irons across the platform.

A5.2 Shear Operation in Plate Shop Possible Interventions

The primary intervention for the shear press operator is to provide adjustable lift tables for cut materials at the back of the shear machine in lieu of the sloped tray.

A6. CONCLUSIONS AND RECOMMENDATIONS

The unloading of angle iron in the steelyard was analyzed using a number of exposure assessment techniques. The high amount of effort required to separate and flip individual pieces of long angle irons is a risk factor associated with this process. Possible interventions include using the mobile crane to spread the stack of angle irons across the platform when dropped and automating some of the processes to eliminate the pulling of angle irons into position across the platform.

The shear press operator often bends at the waist to pick up pieces of steel or to attach them to the jib crane. Manually lifting the pieces of steel from near floor level results in undue stress on the back of the workers. By incorporating lift tables or tilting pallet jacks into areas both in front and behind the shear machine one can minimize the stress on the workers backs. Each of the interventions highlighted here for the two processes will be discussed in much greater detail in a forthcoming report.

It is recommended that further action be taken to mitigate the exposure to musculoskeletal risk factors within each of the identified tasks. The implementation of ergonomic interventions has been found to reduce the amount and severity of musculoskeletal disorders within the working population in various industries.

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University of Michigan Software, *3D Static Strength Prediction Program Version 4.0*, 3003 State St., #2071 Ann Arbor, MI 48109-1280, Copyright 1997 The Regents of The University of Michigan.

A8. TABLES

A8.1 Gator Bar Worker

Table 1. Gator Bar Worker RULA

Rapid Upper Limb Assessment (RULA) (Matamney and Corlett, 1993)

Date/ Time Facility: Area/ Shop: Steelyard
Task : Angle iron positioning by gator bar worker Performed by: Steve Wurzelbacher

RULA Component	Frame # 15990		Frame # 16170		Frame # 16470		Frame # 17190		Composite *(of most common postures from frames 24660 - 27330)*	
	Specific	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*
Shoulder Extension/ Flexion	sl flex	2	ext	2	ext	2	mod flex	3	sl flex (44%)	2
Shoulder is Raised (+1)		0		1		1		0		0
Upper Arm Abducted (+1)		0		1		1		0		0
Arm supported, leaning (-1)		0		0		0		0		0
Elbow Extension/ Flexion	ext	1	neut	2	flex	2	ext	1	ext (60%)	1
Shoulder Abduction/ Adduction	neut	0	m abd	1	hyp abd	1	add	1	neut (65%)	0
Shoulder Lateral/ Medial	neut	0	lat	1	lat	1	m med	1	neut (69%)	0
Wrist Extension/ Flexion	ext	2	ext	2	flx	2	ext	2	ext (44%)	2
Wrist Deviation	rad	1	rad	1	ulnar	1	ulnar	1	ulnar or rad (62%)	1
Wrist Bent from Midline (+1)		0		0		0		0		0
Wrist Twist (1) In mid range Or (2) End of range		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		1		1		1
Arm and Wrist Force/ load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2)		2		2		2		2		2

If more than 10 kg load or repeated or shocks: (+3)										
Neck Extension/ Flexion		2		2		2		2		2
Neck Twist (+1)		0		1		0		0		0
Neck Side-Bent (+1)		0		1		0		0		0
Trunk Extension/ Flexion	mod flex	3	sl flex	2	sl flex	2	hyp flex	4	sl flex (35%)	2
Trunk Twist (+1)		1		0		0		0		0
Trunk Side Bend (+1)		1		1		1		0		1
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		2		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		1		1		1
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		2		2		2		2
Total RULA Score	**7**		**7**		**7**		**7**		**7**	

1 or 2 = ACCEPTABLE
3 or 4 = INVESTIGATE FURTHER
5 or 6 = INVESTIGATE FURTHER AND CHANGE SOON
7 = INVESTIGATE AND CHANGE IMMEDIATELY

Table 2. Gator Bar Worker Strain Index

STRAIN INDEX: DISTAL UPPER EXTREMITY (DUE) DISORDERS RISK ASSESSMENT
(Moore and Garg, 1995)

LOCATION:

TASK: Angle iron positioning by gator bar worker

1. **Intensity of Exertion:** An estimate of the strength required to perform the task one time. Circle the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	***% MS*** (percentage of maximal strength)	***Borg Scale*** (Compare to Borg Cr-10 Scale)	***Perceived Effort***	***Rating*** (circle)	***Multiplier***
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1
Somewhat hard	**10 - 29%**	**3**	**noticeable or definite effort**	**2**	**3**
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression (*28 -38% of observed time > = Hard)	3	6
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13
				Intensity of Exertion Multiplier	**3**

Table 2 (continued). Gator Bar Worker Strain Index

2. **Duration of Exertion (% of cycle)**: Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.***NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0**

Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
% Duration of Exertion	< 10	1	0.5
= 100 x duration of all exertions (sec) / Total observation time (sec)	**10 - 29**	**2**	**1.0**
	30 - 49	3	1.5
= 100 x 546 (sec)/ 984 (sec) = 55	50 -79	4	2.0
	> or = 80	5	3.0
		Duration of Exertion Multiplier	**1.0**

3. **Efforts per Minute:** Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. ***NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0**

Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
Efforts per Minute	< 4	1	0.5
= 100 x number of exertions / Total observation time (min)	4 - 8	2	1.0
	9 -14	**3**	**1.5**
= 100 x [total # of efforts for observed period, 67/ Total observed time (min) 16.39]	15 -19	4	2.0
= 4.1	> or = 20	5	3.0
		Efforts per Minute Multiplier (Fill in)	**1.5**

Table 2 (continued). Gator Bar Worker Strain Index

4. **Hand/ Wrist Posture:** An estimate of the position of the hand or wrist relative to neutral position. Circle the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	***Wrist Extension*** (Stetson et al, 1991)	***Wrist Flexion*** (Stetson et al, 1991	***Ulnar Deviation*** (Stetson et al, 1991	***Perceived Posture***	***Rating*** (circle)	***Multiplier***
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral	3	1.5
Bad	**41 - 55 degrees**	**31 - 50 degrees**	**21 -25 degrees**	**marked deviation**	**4**	**2.0**
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
					Hand/ Wrist Posture Multiplier	**2.0**

Table 2 (continued). Gator Bar Worker Strain Index

5. **Speed of Work:** An estimate of how fast the worker is working. Circle the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	***Compared to MTM*** -1 (observed pace is divided by MTM's predicted pace and expressed as % ; See Barnes 1980)	***Perceived Speed***	***Rating*** (circle)	***Multiplier***
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	**91 -100%**	**"normal" speed of motion**	**3**	**1.0**
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed and barely or unable to keep up	5	2.0
			Speed of Work Multiplier	**1.0**

6. **Duration of Task per Day:** Either measured or obtained from plant personnel. Circle the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Worksheet:	***Rating Criterion***	***Rating*** (circle)	***Multiplier***
Duration of Task per Day (hrs)	< or = 1 hrs	1	0.25
= duration of task (hrs) + duration of task (hrs) + ...	**1 - 2 hrs**	**2**	**0.50**
	2 - 4 hrs	3	0.75
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
		Duration of Task per Day Multiplier	**0.50**

Table 2 (continued). Gator Bar Worker Strain Index

Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion **3** x	**Duration of Exertion** **1** x	**Efforts per Minute** **1.5** x	**Hand/ Wrist Posture** **2** x	**Speed of Work** **1** x	**Duration of Task** **.50**	**=**	**SI SCORE** **4.5**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:

– SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;

– SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;

– SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;

– SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 3. Gator Bar Worker UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders

(Lifshitz and Armstrong, 1986)

Date/ Time Facility Area/ Shop Steelyard

Task Gator Bar Worker Performed by: Steve Wurzelbacher

* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	No	Yes
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges	N	
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?		Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?		Y
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?		Y
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?		Y
6.3 Is the handle of the tool made from material other than metal?	N	
6.4 Is the weight of the tool below 4 kg (9lbs)?	N (~12 lbs)	
6.5 Is the tool suspended?	N	
TOTAL	14 (67%)	7 (33%)

Table 4. Gator Bar Worker OWAS

OWAS: OVAKO Work Analysis System (Louhevaara and Suurnäkki, 1992)

Procedure: Observe workers at intervals of 30-60 seconds and record the postures and forces over a representative period (~ 45 minutes)

Date/ Time Facility Area/ Shop: Steelyard

Task: Angle iron positioning by gator bar worker Performed by: Steve Wurzelbacher

	Work Phase1: **Grasp angle with jaw end (horizontal slot) of bar**	**Work Phase 2** **Flip angle over with bar (beginning)**	**Work Phase 3** **Flip angle over with bar (middle)**	**Work Phase 4** **Flip angle over with bar (end)**	**Work Phase 5** **Reposition towards angles**
TOTAL Combination Posture Score	***2***	***4***	***1***	***3***	***1***
Common Posture Combinations (collapsed across work phases)					
Back	4	4	1	2	
Arms	2	1	1	1	
Legs	2	4	7	7	
Posture Repetition (% of working time)	7	2	7	6	
BACK % of Working Time SCORE	***1***	***1***	***1***	***1***	
ARMS % of Working Time SCORE	***1***	***1***	***1***	***1***	
LEGS % of Working Time SCORE	***1***	***1***	***1***	***1***	
ACTION CATEGORIES: ***1 = no corrective measures*** ***2 = corrective measures in the near future*** ***3 = corrective measures as soon as possible*** ***4 = corrective measures immediately***					
Risk Factor	**Work Phase1:** **Grasp angle with jaw end (horizontal**	**Work Phase 2** **Flip angle over with bar**	**Work Phase 3** **Flip angle over with bar (middle)**	**Work Phase 4** **Flip angle over with bar (end)**	**Work Phase 5** **Reposition towards angles**

	slot) of bar	(beginning)			
Posture					
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	4	4	1	2	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	2	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	2	4	7	7	7
Load/ Use of Force					
1 = weight or force needed is = or <10 kg 2 = weight or force > 10 but < 20kg 3 = weight or force > 20 kg	1	2	2	2	1
Phase Repetition					
% of working time (0,10,20,30,40,50,60,70,80,90,100)	07	02	02	06	05

Table 4 (continued). Gator Bar Worker OWAS

Table 5. Gator Bar Worker PLIBEL

PLIBEL Checklist (Kemmlert, 1995)

Date/ Time: Facility:
Area/ Shop: Steelyard
Task: Angle iron positioning by gator bar worker Performed by: Steve Wurzelbacher

Section I: Musculoskeletal Risk Factors
Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions (Preferred Method)
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	*Body Regions*				
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
1: Is the walking surface uneven, sloping, slippery or non-resilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			Y	Y	Y
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing legwork performed? E.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	Y				Y
d) severely twisted?	Y				Y

Table 5 (continued). Gator Bar Worker PLIBEL

10: Is repeated or sustained work performed when the neck is:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	Y				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Notice factors of importance as:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	N				N
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	Y				Y
f) handling below knee length	N				N
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	N				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		Y			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 5 (continued). Gator Bar Worker PLIBEL

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
SUM	15	9	3	3	11
PERCENTAGE	57.7	81.8	37.5	37.5	52.4

Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores	
18: Is there no possibility to take breaks and pauses?	N
19: Is there no possibility to choose order and type of work tasks or pace of work	Y
20: Is the job performed under time demands or psychological stress	N
21:Can the work have unusual or expected situations?	N
22: Are the following present?	
a) cold	N
b) heat	Y
c) draft	N
d) noise	Y
e) troublesome visual conditions	N
f) jerks, shakes, or vibration	N
Environmental / Organizational Risk Factors Score	
SUM	3
PERCENTAGE	30.0

A8.2 Table 6. Shear Press Operator UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders

(Lifshitz and Armstrong, 1986)

Date/ Time Facility Area/Shop: Plate shop

Task Shear Press Operator Performed by: Steve Wurzelbacher

* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	**No**	**Yes**
1**. Physical Stress**		
1.1 Can the job be done without hand/ wrist contact with sharp edges	N	
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21 degrees C (70 degrees F)?		Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	n/a	n/a
3.3 Can the job be done without deviating the wrist from side to side?		Y
3.4 Can the tool be used without deviating the wrist from side to side?		Y
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	n/a	n/a
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?		Y
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	n/a	n/a
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	n/a	n/a
6.3 Is the handle of the tool made from material other than metal?	n/a	n/a
6.4 Is the weight of the tool below 4 kg (9lbs)?	n/a	n/a
6.5 Is the tool suspended?	n/a	n/a
TOTAL	7 (50 %)	7 (50 %)

Table 7. Shear Press Operator NIOSH Manual Materials Handling Checklist

NIOSH Hazard Evaluation Checklist for Lifting, Carrying, Pushing, or Pulling (Waters and Putz-Anderson, 1996)

Date/ Time Facility Area/ Shop: Plate Shop

Task Shear Press Operator Performed by: Steve Wurzelbacher

RISK FACTORS	*YES*	*NO*
General		
1.1 Does the load handled exceed 50 lbs?		*N*
1.2 Is the object difficult to bring close to the body because of it's size, bulk, or shape?	*Y*	
1.3 Is the load hard to handle because it lacks handles or cutouts for handles, or does it have slippery surfaces or sharp edges?	*Y*	
1.4 Is the footing unsafe? For example, are the floors slippery, inclined, or uneven?	*Y (ridges at shear press back)*	
1.5 Does the task require fast movement, such as throwing, swinging, or rapid walking?		*N*
1.6 Does the task require stressful body postures such as stooping to the floor, twisting, reaching overhead, or excessive lateral bending?	*Y (extreme lumbar flexion)*	
1.7 Is most of the load handled by only one hand, arm, or shoulder?		*N*
1.8 Does the task require working in environmental hazards, such as extreme temperatures, noise, vibration, lighting, or airborne contamination?		*N*
1.9 Does the task require working in a confined area?		*N*
Specific		
2.1 Does the lifting frequency exceed 5 lifts per minute (LPM)?		*N (LPM = 0.10 over total observed time of 10 minutes)*
2.2 Does the vertical lifting distance exceed 3 feet?	*Y*	
2.3 Do carries last longer than 1 minute?		*N*
2.4 Do tasks which require large sustained pushing or pulling forces exceed 30 seconds duration?		*N*
2.5 Do extended reach static holding tasks exceed 1 minute?		*N*
TOTAL	*5 (36 %)*	*9 (64 %)*

* "YES" responses are indicative of conditions that pose a risk of developing low back pain; the larger the percentage of "YES" responses, the greater the risk.

Table 8. Shear Press Operator NIOSH Lifting Equation Analysis

NIOSH Lifting Equation (Waters, Putz-Anderson, Garg, and Fine, 1993)

Date/ Time Facility Area/ Shop: Plate Shop
Task: Shear Press Operator Plate Lift from Back of Shear Performed by: Steve Wurzelbacher

Duration: 1 hour	**Average Object Weight: 20 pounds**	**Maximum Object Weight: 51 pounds**
ORIGIN VARIABLE	***ORIGIN VALUE***	***ORIGIN MULTIPLIER***
Horizontal Location, H	24 inches	0.42
Vertical Location, V	7 inches	0.83
Travel Distance, D	29 inches	0.89
Asymmetric Angle, A	40 degrees	0.87
Frequency, F	0.16 lifts/minute	1.00
Hand to Object Coupling, C	Poor	0.90
DESTINATION VARIABLE	***DESTINATION VALUE***	***DESTINATION MULTIPLIER***
Horizontal Location, H	10 inches	1.00
Vertical Location, V	31 inches	0.99
Travel Distance, D	29 inches	0.89
Asymmetric Angle, A	40 degrees	0.87
Frequency, F	0.16 lifts/minute	1.00
Hand to Object Coupling, C	Poor	0.90
RESULTS	***ORIGIN***	***DESTINATION***
Recommended Weight Limit (RWL)	12.4 pounds	35.2 pounds
Lifting Index, LI (RWL/Load)	1.61	
Population Capable	Male = 92 % Capable Female = 41 % Capable	

Table 9. Shear Press Operator 3D Static Strength Prediction Program

3D Static Strength Prediction Program (University of Michigan, 1997)

Date/ Time: *Facility:*
Area/ Shop: PlateShop *Task:* Plate pick up from back of shear

Work Element: Shear Press Operation	**Disc Compression (lbs) @ L5/S1** (Note: NIOSH Recommended Compression Limit (RCL) is 770 lbs)
One-handed pick-up of plate from back of shear. Plate weighs 20 lbs; lifts plate off shelf at back of tray, then drops plate into bin; 20 lbs in right hand	673 lbs. (middle of lift)

Table 10. Shear Press Operator PLIBEL

PLIBEL Checklist (Kemmlert, 1995)

Date/ Time: Facility:

Area/ Shop: Plate Shop

Task: Shear Press Operator Performed by: Steve Wurzelbacher

Section I: Musculoskeletal Risk Factors

Methods of Application:

1) Find the injured body region, answer yes or no to corresponding questions (Preferred Method)
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	*Body Regions*				
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
1: Is the walking surface uneven, sloping, slippery or non-resilient?			N	N	N
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	N	N	N	N	N
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			Y	Y	Y
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing legwork performed? E.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 10 (continued). Shear Press Operator PLIBEL

10: Is repeated or sustained work performed when the neck is:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Notice factors of importance as:					
a) periods of repetitive lifting	N				N
b) weight of load	Y				Y
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	Y				Y
e) handling beyond forearm length	Y				Y
f) handling below knee length	Y				Y
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	N	N			N
13: Is sustained work performed when one arm reaches forward or to the side without support?	N				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	N	N			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		N			
c) uncomfortable hand positions?		N			
d) switches or keyboards?		N			

Table 10 (continued). Shear Press Operator PLIBEL

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
SUM	12	3	1	1	9
PERCENTAGE	46.2	27.3	12.5	12.5	42.9

Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores	
18: Is there no possibility to take breaks and pauses?	N
19: Is there no possibility to choose order and type of work tasks or pace of work	N
20: Is the job performed under time demands or psychological stress	N
21:Can the work have unusual or expected situations?	Y
22: Are the following present?	
a) cold	N
b) heat	Y
c) draft	N
d) noise	Y
e) troublesome visual conditions	N
f) jerks, shakes, or vibration	N
Environmental / Organizational Risk Factors Score	
SUM	3
PERCENTAGE	30.0

APPENDIX B

PRE-INTERVENTION QUALITATIVE ERGONOMIC HAZARD ANALYSIS

WORK TASKS ANALYZED:

RAKE FRAME SUBASSEMBLIES

ANGLE IRON UNLOAD WITHIN THE STEELYARD

HONEYCOMB WELDING

Three specific processes were identified for further analysis. These processes were: rake frame subassemblies within the Structural Shop, angle iron unload within the Steelyard, and honeycomb welding within the Line Four Hull area. Each of these processes are examined in greater detail below.

B1. Rake Frame Subassemblies within Structural Shop

B1.1. Injury Data

This area within the shipyard has the highest overall musculoskeletal disorder (MSD) incidence rate, is second within the shipyard in MSD Days Away From Work incidence rate at 3.5 cases per 100 FTE, and third within the shipyard in MSD back incidence rate. Examples of recent injuries include: lower back strain when angle iron being lifted slipped, bursitis in knee aggravated by crawling on stern units, and bilateral wrist tendonitis from repetitive use of handtools and holding steel in place.

B1.2. Process

Subassemblies such as rake frames, or the skeletal framework for the curved bows, for tanker, chemical, and cargo barges are created in this area. Three stations exist for each type of rake frame, at approximately 21.5 feet x 36 feet each. Jigs are set-up at ground-level being welded in place on the steel deck floor. The overall rake frame process is as follows:

1) Delivery of angle irons by overhead crane (ranging in size and shape) to stacks parallel to the jig set-up.

2) Place angle irons manually into the jig, usually done by one shipfitter, sometimes in tandem lifts. This placement requires to bend extremely at the waist and to lift loads up to about 125 pounds. Workers who do this job are very skilled and tend to slide and pivot the larger angle irons into place rather than lift the entire load. Smaller irons (ranging in size from 45 to 90 pounds) are still often lifted entirely by hand.

Figure 4. Shipfitter moving angle iron from stockpile to jig

Figure 5. Shipfitter placing smaller angle iron into jig

3) Angle irons are adjusted into place by the shipfitter using their hands and gator pry bar to grip the angle irons. Wedges are then hammered into place to hold the irons in place in the jig.

4) Horizontal plates at the corners of the rake frame are manually lifted, positioned on the frame and held in place by the use of C-clamps, as are the smaller angle irons.

Figure 6. Shipfitter holding angle irons together with C-clamps

5) A team of 2 welders stick weld the joints of the rake frame that face up. Postures assumed during welding are typically bent at the waist, kneeling, or sitting on the rake frame.

Figure 7. Welding rake frame angle irons while standing

Figure 8. Welding rake frame angle irons while squatting

6) The rake frame subassembly is released by the shipfitter knocking out the wedges with a hammer. The rake frame subassembly is then picked up, flipped over, and

moved to an area adjacent to the jig by the overhead crane. Frames are stacked in piles of 6-7 frames.

7) The welders move to the stack of frames and weld the joints that are now facing up. During this process, the shipfitter and the welders are working at the same time so that one frame is being set up as the other is being finished welded together. Approximately 18-21 of these frames are done a day.

The most common trades employed within the Structural Shop are welders and shipfitters.

B1.3. Ergonomic Risk Factors

During rake frame subassembly, shipfitters undergo awkward postures including extreme lumbar flexion and excessive loads to low back. Welders undertake awkward postures such as extreme lumbar flexion, shoulder abduction, wrist flexion, both ulnar and radial deviation, and kneeling on hard surfaces.

B1.4. Ergonomic Analysis of Shipfitters in Rake Frame Subassembly

Using several of the exposure assessment tools outlined above, an ergonomic analysis was performed for the shipfitter in the rake frame subassembly task. A RULA analysis was not deemed appropriate since the primary concern with the shipfitter at this task appears to be manual materials handling and poor back posture and the RULA primarily addresses the upper limb. A Strain Index analysis was performed (B7.1. Table 1) with the following results:

1) the Intensity of Exertion was rated as "Hard" and given a multiplier score of 6 on a scale of 1 to 13
2) the Duration of the task was rated as 50 - 79 per cent of the task cycle, resulting in a multiplier of 2.0 on a scale of 0.5 to 3.0
3) the Efforts per Minute were noted to be between 4 and 8, resulting in a multiplier of 1.0 on a scale of 0.5 to 3.0
4) the Hand/Wrist posture was rated as "Good," resulting in a multiplier of 1.0 on a scale of 1.0 to 3.0
5) the Speed of Work was rated as "Normal," resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
6) the Duration of Task per Day was rated to be between 2 and 4 hours, resulting in a multiplier of 0.75 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 9. An SI score of between 5 and 30 is correlated to an incidence rate of about 77 distal upper extremity injuries per 100 FTE. Regardless of actual incidence rate, the Strain Index indicates that this task puts the worker at increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the rake frame shipfitter task (B7.1. Table 2), of the 21 possible responses, eight were negative, six were positive, and seven were not applicable. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the rake frame shipfitter task (B7.1. Table 3), corrective measures were suggested for a number of specific sub-tasks. These sub-tasks include: placing the angle iron, clamping and unclamping the angle iron, hammering wedges to tighten angle irons in the jig, de-slagging the welds, and staging the angle irons prior to use.

The NIOSH checklist for manual materials handling consists of 14 items. When applied to the rake frame shipfitter task (B7.1. Table 4), six responses were positive and eight negative. In this checklist, positive responses are indicative of conditions that pose a risk to the worker of developing low back pain. The higher the percentage of positive response, the greater the risk of low back pain. For the rake frame shipfitter task, this percentage was 43 per cent.

The University of Michigan 3D Static Strength Prediction Program was used to analyze eight rake frame shipfitter sub-tasks (B7.1. Table 5). Analysis of these sub-tasks resulted in estimated disc compression loads at the L5/S1 disc to be in excess of the NIOSH Recommended Compression Limit of 770 pounds for seven of the eight subtasks. The average estimated disc compression load was 923 pounds. The maximum estimated disc compression load was 1531 pounds, nearly twice the recommended limit.

The PLIBEL checklist for the rake frame shipfitter task (B7.1. Table 6) reports a high percentage (> 70 per cent) of risk factors present for the neck, shoulder, upper back, elbows, forearms, hands, and lower back. Several environmental and organizational modifying factors are present as well.

B1.5. Ergonomic Analysis of Welders in Rake Frame Subassembly

A Rapid Upper Limb Assessment was conducted for the rake frame welder tasks (B7.2. Table 7). Analyses of four tasks with unique postures and a composite task each resulted in a response to “investigate and change immediately.”

A Strain Index analysis was performed for the rake frame welders (B7.2. Table 8) with the following results:

1) the Intensity of Exertion was rated as “Somewhat Hard” and given a multiplier score of 3 on a scale of 1 to 13

2) the Duration of the task was rated as 50 - 79 per cent of the task cycle, resulting in a multiplier of 2.0 on a scale of 0.5 to 3.0

3) the Efforts per Minute were noted to be nearly continuous at greater than or equal to 20 per minute, resulting in a multiplier of 3.0 on a scale of 0.5 to 3.0

4) the Hand/Wrist posture was rated as “Fair,” resulting in a multiplier of 1.0 on a scale of 1.0 to 3.0

5) the Speed of Work was rated as “Normal,” resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0

6) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a multiplier of 1.0 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For the rake frame welder tasks the final SI score was 27. An SI score of between 5 and 30 is correlated to an incidence rate of about 77 distal upper extremity injuries per 100 FTE. Regardless of actual incidence rate, the Strain Index indicates that this task puts the worker at increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the rake frame welder task (B7.2. Table 9), of the 21 items, ten were negative and twelve were positive (one item answered both positively and negatively). Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the rake frame welder task (B7.2. Table 10), "corrective measures in the near future" were suggested for a number of specific sub-tasks. These sub-tasks include: welding from inside the rake frame, welding while straddling the rake frame, welding from outside the rake frame, and de-slagging the welds.

The PLIBEL checklist for the rake frame welder task (B7.2. Table 11) reports a moderate percentage (approximately 50 per cent) of risk factors present for the neck, shoulder, upper back, elbows, forearms and hands. Several environmental and organizational modifying factors are present as well.

B2. Angle Iron Unload in Steelyard

Figure 9. Steelyard conveyor system

B2.1. Injury Data

Injury data specific to workers in the steelyard could not be determined from available information.

B2.2. Process

Raw material, primarily steel plate and angle irons, is brought to the shipyard by truck, train or barge. Material is placed within the steelyard by the use of an A-frame crane and stored outside until needed by the various production departments. Task under consideration is the separation of angle iron from batch loads. The type of angle iron used within the shipyard varies greatly in size, length and weight. Common angle irons are 5 inches by 3 inches by forty feet in length and 5/16 inch thick. A general description of angle iron separation process follows:

1) Large A-frame crane picks up batch load of angle irons from steelyard and transports it to an unloading station
2) After the crane releases the load on a large stand, the steel bands holding the batch together are cut using a set of shears and one worker begins separating the load with a gator bar, which is about 3 feet long, and weighs 12.2 pounds

Figure 10. Separating angle irons with gator bar

3) The worker grabs hold of each individual iron with the gator bar and lets it fall onto a sorting table below.

Figure 11. Flipping angle irons onto conveyor with gator bar

4) Two workers then pull the angle across the table either by hand or with large, long hooks and spread the angle irons across the roller conveyor.

Figure 12. Workers positioning angle iron on roller conveyor

5) Once the angle irons are placed on the roller conveyor, the angle irons are transferred to a mobile conveyor section that places the angle irons into the surface preparation process.

B2.3. Ergonomic Risk Factors

The gator bar worker experiences awkward postures including extreme lumbar flexion and excessive shoulder loads in separating the angle irons apart. The unload helpers also experience awkward postures including moderate lumbar flexion and moderate shoulder loads in pulling the angle irons across the roller conveyor.

B2.4. Ergonomic Analysis of Gator Bar Worker

A Rapid Upper Limb Assessment was conducted for the gator bar worker and the angle iron separation tasks (B7.3. Table 12). Analyses of four tasks with unique postures and a composite task each resulted in a response to “investigate and change immediately.”

A Strain Index analysis was performed for the gator bar worker separating angle irons (B7.3. Table 13) with the following results:

1) the Intensity of Exertion was rated as “Very Hard” and given a multiplier score of 9 on a scale of 1 to 13

2) the Duration of the task was rated as 10 - 29 per cent of the task cycle, resulting in a multiplier of 1.0 on a scale of 0.5 to 3.0

3) the Efforts per Minute were recorded to be between 9 and 14 resulting in a multiplier of 1.5 on a scale of 0.5 to 3.0

4) the Hand/Wrist posture was rated as “Bad,” resulting in a multiplier of 2.0 on a scale of 1.0 to 3.0

5) the Speed of Work was rated as “Normal,” resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0

6) the Duration of Task per Day was rated to be between 1 and 2 hours, resulting in a multiplier of 0.50 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For the gator bar worker separating angle iron the final SI score was 13.5. An SI score of between 5 and 30 is correlated to an incidence rate of about 77 distal upper extremity injuries per 100 FTE. Regardless of actual incidence rate, the Strain Index indicates that this task puts the worker at increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the gator bar worker separating angle irons (B7.3. Table 14), of the 21 items, fifteen were negative and six were positive (one item answered both positively and negatively, one item not answered). Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the gator bar worker separating angle irons (B7.3. Table 15), “corrective measures in the near future” were suggested for the sub-task of using the jaw end of the gator bar to flip the angle irons. Analyses of three other sub-tasks resulted in the response “corrective measures immediately.” These sub-tasks include: using the jaw end of the gator bar to separate angle irons, and using the pry end of the gator bar to either separate the angle irons or to lever the angle irons over.

The PLIBEL checklist for the gator bar worker separating angle irons (B7.3. Table 16) reports a high percentage (approximately 80 per cent) of risk factors present for the elbows, forearms, and hands. Moderate percentages (approximately 50 per cent) of risk factors are present for the neck, shoulder, upper back and low back. A high percentage (approximately 80 per cent) of environmental and organizational modifying factors are present as well.

B2.5. Ergonomic Analysis of Steelyard Helper

A Rapid Upper Limb Assessment was conducted for the steelyard helper in the angle iron flip and layout tasks (B7.3. Table 17). Analysis of one task resulted in a response of “investigate further and change soon.” Analyses of three other tasks with unique postures and a composite task each resulted in a response to “investigate and change immediately.”

A Strain Index analysis was performed for the steelyard helper in the angle iron flip and layout tasks (B7.3. Table 18) with the following results:

1) the Intensity of Exertion was rated as “Somewhat Hard” and given a multiplier score of 3 on a scale of 1 to 13

2) the Duration of the task was rated as 30 - 49 per cent of the task cycle, resulting in a multiplier of 1.5 on a scale of 0.5 to 3.0

3) the Efforts per Minute were recorded to be between 9 and 14 resulting in a multiplier of 1.5 on a scale of 0.5 to 3.0

4) the Hand/Wrist posture was rated a “Bad,” resulting in a multiplier of 2.0 on a scale of 1.0 to 3.0

5) the Speed of Work was rated as “Normal,” resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0

6) the Duration of Task per Day was rated to be between 2 and 4 hours, resulting in a multiplier of 0.75 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For the steelyard helper at the angle iron task, the final SI score was 10.1. An SI score of between 5 and 30 is correlated to an incidence rate of about 77 distal upper extremity injuries per 100 FTE. Regardless of actual incidence rate, the Strain Index indicates that this task puts the worker at increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the steelyard helper at the angle iron task (B7.3. Table 19), of the 21 items, fourteen were negative and seven were positive (one item answered both positively and negatively, one item not answered). Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the steelyard helper at the angle iron task (B7.3. Table 20), "corrective measures in the near future" or "corrective measures as soon as possible"were suggested for the sub-task of dragging the angle iron along the roller conveyor. Analysis of the sub-tasks of using the jaw end of a gator bar to flip the angle iron resulted in the response "corrective measures as soon as possible."

The PLIBEL checklist for the steelyard helper at the angle iron task (B7.3. Table 21) reports a high percentage (approximately 73 per cent) of risk factors present for the elbows, forearms, and hands. A moderate percentage (approximately 42 per cent) of risk factors are present for the neck, shoulder, and upper back. A moderate percentage (approximately 60 per cent) of environmental and organizational modifying factors are present as well.

B3. Honeycomb Welding in Line Four Hull Area

Figure 13. Honeycomb Confined Space Welding at Line Four Hull Area

B3.1. Injury Data

The honeycomb welding task within the Line Four Hull area is often the initial job of new hires once they meet the welding school qualifications. This task also tends to be somewhat difficult. The worker must enter a 2 foot by 2 foot by 16 foot long section of hull and stitch weld the bottom steel plate to the vertical supports on both sides for the entire length using a stick welding process. The confined space can lead to awkward postures, particularly for larger individuals. This area of the shipyard is fourth in the overall number of musculoskeletal disorders, fourth in the number of musculoskeletal disorder Days Away from Work cases, and second in musculoskeletal disorder actual number of days away from work. All workers at this area are welders. Recent injuries include: four ankle injuries due to slips and trips while moving between honeycombs; four low back injuries from slips, manual materials lifting, or pulling welding leads; three knee injuries from slips and contact stresses; and three arm, wrist, or elbow injuries from pulling welding leads.

B3.2. Process

The Line Four Hull area is responsible for welding the double hulls for chemical and liquid tankers. This involves welding in spaces known as honeycombs which are two feet by two feet by sixteen feet long. The bottom plate is welded to the vertical supports on both sides of the honeycomb. Currently, a stick welding process is used. Typically 8-10 honeycombs can be completed in a shift by each welder. Ventilation is primarily by blower fan forcing outside air into the honeycomb. A detailed report on ventilation interventions for this process can be found at NIOSH.

Figure 14. Constrained Posture of Confined Space Honeycomb Welder

B3.3. Ergonomic Risk Factors

The welders must assume constrained postures in order to crawl to the far end of the honeycomb to begin welding. This task also includes extreme lumbar flexion in confined spaces, contact stress on the knees and elbows, pulling and lifting weld leads into and out of the honeycomb, positioning the blower fan and moving it from one honeycomb to the next, and extreme environmental temperatures in summer and winter.

B3.4. Ergonomic Analysis of Honeycomb Welder in Line Four Hull Area

A Rapid Upper Limb Assessment was conducted for the honeycomb welder task (B7.4. Table 22). Analyses of four tasks with unique postures and a composite task each resulted in a response to "investigate and change immediately."

A Strain Index analysis was performed for the honeycomb welder task (B7.4. Table 23) with the following results:

the Intensity of Exertion was rated as "Somewhat Hard" and given a multiplier score of 3 on a scale of 1 to 13

1) the Duration of the task was rated as 50 - 79 per cent of the task cycle, resulting in a multiplier of 2.0 on a scale of 0.5 to 3.0

2) the Efforts per Minute were recorded to be extremely static due to the nature of the process resulting in a multiplier of 3.0 on a scale of 0.5 to 3.0

3) the Hand/Wrist posture was rated as “Fair,” resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0

4) the Speed of Work was rated as “Normal,” resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0

5) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a multiplier of 1.00 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For the honeycomb welder task the final SI score was 27. An SI score of between 5 and 30 is correlated to an incidence rate of about 77 distal upper extremity injuries per 100 FTE. Regardless of actual incidence rate, the Strain Index indicates that this task puts the worker at increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the honeycomb welder task (B7.4. Table 24), of the 21 items, ten were negative and eleven were positive. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the honeycomb welder task (B7.4. Table 25), "corrective measures in the near future" were suggested for the sub-tasks of striking the welding arc and running the bead, de-slagging the weld, and changing out the welding sticks if the back was not twisted. Otherwise, if the back was twisted, each of the sub-tasks resulted in a response to implement "corrective measure immediately."

The PLIBEL checklist for the honeycomb welder task (B7.4. Table 26) reports a high percentage (approximately 80 per cent) of risk factors present for the elbows, forearms, and hands. Moderate percentages (approximately 50 -65 per cent) of risk factors are present for the neck, shoulder, upper back, low back, feet, knees and hips. A high percentage (approximately 80 per cent) of environmental and organizational modifying factors are present as well.

B4 CONTROL TECHNOLOGY

Possible interventions and control technologies are mentioned briefly here. A more detailed report of possible interventions is in press.

B4.1. Rake Frame Subassembly Possible Interventions

An adjustable jig (a jig top placed on a lift table) may offer a solution, and it may be that one jig can be made to fit all three rake frames. This would open more floor space and eliminate the need for the welders and shipfitter to bend. Possible problems with this approach are that some of the workers prefer the low height of the jig because the angles can be pivoted and maneuvered into place easily. Another concern is that the jig would be too high for the crane to offload, but this wouldn't be a problem if the jig could be lowered back down when unloaded. Also, there are concerns that the welders would trip over the raised rake frame, although no welds actually require the welder to be inside of the frame while welding. The only reason that they currently stand inside of the frame while welding is because the angle irons are stacked up parallel to the jig @ 1' away and impede getting around the outside of the frame. This means that the stacking of the material would have to be changed too if the jig is raised, unless the frame can be rotated as it is raised, which might be possible if engine stand type lifts were used. A rotatable jig would also eliminate the need for the crane to flip the frame and also eliminate the problem of welding the frames that are stacked on the ground first. Two years ago, a number of similar changes were made in other areas of the structural shop. Coincidentally or not, the MSD incidence rate dropped dramatically from 16 in 1997 to 5 in 1998.

B4.2. Angle Iron Unload in Steelyard Possible Interventions

An uneven and tilted surface on the stand may help to break the load up as it is released from the crane. Changes in how the load is slung and/or handled by the crane may also help. A simple push mechanism on the unloading table would eliminate the need for the two workers who hook and pull each angle across the table.

B4.3. Confined Space Welding on Line Four Hull Possible Interventions

Possible interventions include the change in weld process from stick to wire welding, the use of creeper carts to allow the worker to roll to the back of the honeycomb section, the installation and automatic welding systems, and improved ventilation systems.

B5. CONCLUSIONS AND RECOMMENDATIONS

Three work processes within a barge building operation were surveyed to determine the presence of risk factors associated with musculoskeletal disorders. The rake frame sub-assembly task requires workers, in the shipfitter trade, to maneuver long steel angle irons into position in a pattern laid out on the shop's steel floor. These long angle irons can weigh up to approximately 240 pounds and are slid or bounced into position between jigs welded onto the floor. Smaller angle irons and steel plates are manually placed to form cross members or corner supports. The combination of manual materials handling and awkward posture of a bent torso to place the material near floor level results in a job the can be considered high in musculoskeletal disorder risk factors. Six separate exposure assessment techniques were used to quantify the risk factors associated with this shipfitter job. A possible intervention is raising the work surface by installing a lift table to hold the jig pattern for the rake frame, eliminating the bent torso for much of the task Welders who join the individual pieces of steel also exhibit awkward postures while working near floor level. By raising the work surface, these awkward postures are minimized.

The unloading of angle iron in the steelyard was also analyzed with a number of exposure assessment techniques. The high amount of effort required to separate and flip individual pieces of long angle iron are some of the risk factors associated with this process. Possible interventions include angling the surface of the stock table to encourage the stack of angle irons to loosen when dropped by the yard crane, and automating some of the processes to eliminate the pulling of angle irons into position across the roller conveyor.

The honeycomb welder task in the manufacture of double hull sections requires the worker to enter a confined space and weld two seams between vertical supports and the bottom steel plate. This process can be improved from current conditions by changing ventilation set-ups, changing from stick to wire welding, or by automating the welding process. This last option may be most desirable to remove the worker from exposure to risk factors. Otherwise, the constrained postures, exposure to contact stresses to the knees and elbows, and exposure to some welding fumes would still be present.

It is recommended that further action be taken to mitigate the exposure to musculoskeletal risk factors within each of the identified tasks. The implementation of ergonomic interventions has been found to reduce the amount and severity of musculoskeletal disorders within the working population in various industries. It is recommended that ergonomic interventions be implemented to minimize hazards in the identified job tasks.

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B7. ERGONOMIC ANALYSIS TABLES

B7.1. Rake Frame Shipfitters

Table 1. Rake Frame Shipfitter Strain Index

STRAIN INDEX: DISTAL UPPER EXTREMITY (DUE) DISORDERS RISK ASSESSMENT

(Moore and Garg, 1995)

LOCATION: Structural Shop, 11/9/99 TASK: Rakeframe Shipfitting

1. **Intensity of Exertion:** An estimate of the strength required to perform the task one time. Circle the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	***% MS*** (percentage of maximal strength)	***Borg Scale*** (Compare to Borg Cr-10 Scale)	***Perceived Effort***	***Rating*** (circle)	***Multiplier***
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3
Hard	**30 - 49%**	**4 - 5**	**obvious effort; unchanged facial expression (*28 -38% of observed time > = Hard)**	**3**	**6**
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13

Intensity of Exertion Multiplier	**6**

Table 1 (continued). Rake Frame Shipfitter Strain Index

2. **Duration of Exertion (% of cycle)**: Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.***NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0**

Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
% Duration of Exertion	< 10	1	0.5
	10 - 29	2	1.0
= 100 x duration of all exertions (sec) / Total observation time (sec)	30 - 49	3	1.5
	50 -79	**4**	**2.0**
= 100 x 546 (sec)/ 984 (sec) = 55 *for cycle "**2 nd keel frame**"	> or = 80	5	3.0
		Duration of Exertion Multiplier	**2.0**

3. **Efforts per Minute:** Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. ***NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0**			
Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
Efforts per Minute = 100 x number of exertions / Total observation time (min) = 100 x [total # of efforts for observed period, 67/ Total observed time (min) 16.39] = 4.1	< 4	1	0.5
	4 - 8	**2**	**1.0**
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	5	3.0
		Efforts per Minute Multiplier (Fill in)	**1.0**

Table 1 (continued). Rake Frame Shipfitter Strain Index

4. **Hand/ Wrist Posture:** An estimate of the position of the hand or wrist relative to neutral position. Circle the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	***Wrist Extension*** (Stetson et al, 1991)	***Wrist Flexion*** (Stetson et al, 1991)	***Ulnar Deviation*** (Stetson et al, 1991)	***Perceived Posture***	***Rating*** (circle)	***Multiplier***
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	**11 - 25 degrees**	**6 - 15 degrees**	**11 -15 degrees**	**near neutral (*estimated, no RULA performed)**	**2**	**1.0**
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
					Hand/ Wrist Posture Multiplier	**1.0**

Table 1 (continued). Rake Frame Shipfitter Strain Index

5. **Speed of Work:** An estimate of how fast the worker is working. Circle the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	***Compared to MTM*** -1 (observed pace is divided by MTM's predicted pace and expressed as % ; See Barnes 1980)	***Perceived Speed***	***Rating*** (circle)	***Multiplier***
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	**91 -100%**	**"normal" speed of motion**	**3**	**1.0**
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed and barely or unable to keep up	5	2.0
Speed of Work Multiplier				1.0

6. **Duration of Task per Day:** Either measured or obtained from plant personnel. Circle the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	***Rating Criterion***	***Rating*** (circle)	***Multiplier***
Duration of Task per Day (hrs)	< or = 1 hrs	1	0.25
= duration of task (hrs) +	1 - 2 hrs	2	0.50
duration of task (hrs) + ...	**2 - 4 hrs**	**3**	**0.75**
	4 - 8 hrs	4	1.00
= (22 frames per day @ 20 minutes per frame-- from mgmt-- 7.3 hrs of frame cycle time @ .55 duration of exertion (See #2) = 4 hrs per day)	> or = 8 hrs	5	1.50
		Duration of Task per Day Multiplier	**0.75**

Table 1 (continued). Rake Frame Shipfitter Strain Index

Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**		**SI SCORE**
6 X	**2 X**	**1 x**	**1 x**	**1 x**	**.75**	**=**	**9**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:

- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;

- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;

- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;

- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 2. Rake Frame Shipfitter UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
(Lifshitz and Armstrong, 1986)

Date/ Time 11/9/99 Facility Area/ Shop Structural Shop : Rakeframe assembly
Task Shipfitter
* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	No*	Yes
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges	N	
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	n/a	n/a
3.3 Can the job be done without deviating the wrist from side to side?		Y
3.4 Can the tool be used without deviating the wrist from side to side?		Y
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	n/a	n/a

5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?		Y
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	n/a	n/a
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	n/a	n/a
6.3 Is the handle of the tool made from material other than metal?	n/a	n/a
6.4 Is the weight of the tool below 4 kg (9lbs)?	n/a	n/a
6.5 Is the tool suspended?	n/a	n/a
TOTAL	8	7

Table 3. Rake Frame Shipfitter OWAS

OWAS: OVAKO Work Analysis System
(Louhevaara and Suurnäkki, 1992)

Procedure: Observe workers at intervals of 30-60 seconds and record the postures and forces over a representative period (~ 45 minutes)

Date/ Time 11/9/99 Facility Area/ Shop Structural Shop : Rakeframe assembly
Task Shipfitter

Risk Factor	Work Phase 1 Place Angle Irons	Work Phase 2 Clamp/ un-Clamp	Work Phase 3 Hammer Wedges	Work Phase 4 De-Slag	Work Phase 5 Stage Angles	Work Phase 6 Rest	Work Phase 7 Un-Defined	Work Phase 8 Torch Cut	Work Phase 9 Place Angle Pieces
TOTAL Combination Posture Score	***3, 4***	***2, 4***	***2, 4***	***2, 4***	***3, 4***	***1***	***1***	***2***	***2, 3, 4***
Common Posture Combinations (collapsed across work phases)									
Back	4	1	2	4	2	2	1		
Arms	1	1	1	1	1	1	1		
Legs	7	1	4	4	7	4	2		
Posture Repetition (% of working time)	51	45	4	51*	51*	55*	4*		
BACK % of Working Time SCORE	***3***	***1***	***1***	3	2	2	1		
ARMS % of Working Time SCORE	***1***	***1***	***1***	1	1	1	1		
LEGS % of Working Time SCORE	***1***	***1***	***1***	3	1	3	1		
ACTION CATEGORIES: ***1 = no corrective measures*** ***2 = corrective measures in the near future*** ***3 = corrective measures as soon as possible*** ***4 = corrective measures immediately***									
Risk Factor	**Work Phase 1**	**Work Phase 2**	**Work Phase 3**	**Work Phase 4**	**Work Phase 5**	**Work Phase 6**	**Work Phase 7**	**Work Phase 8**	**Work Phase 9**

	Place Angle Irons	Clamp/ un-Clamp	Hammer Wedges	De- Slag	Stage Angles	Rest	Un-Defined	Torch Cut	Place Angle Pieces
Posture									
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2,4	2,4	2,4	2,4	2,4	1	1	2	2,4
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	7	4, 7	4,7	4,7	4,7	1,2	1,2	4	4,7
Load/ Use of Force									
1 = weight or force needed is = or <10 kg (<22lbs) 2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs) 3 = weight or force > 20 kg (>44 lbs)	3	1	1	1	3	1	1	1	2
Phase Repetition									
% of working time: (0,10,20,30,40,50,60,70,80,90,100)	10	18	7	13	1	5	40	4	2

Table 3 (continued). Rake Frame Shipfitter OWAS

Table 4. Rake Frame Shipfitter NIOSH Manual Materials Handling Checklist

NIOSH Hazard Evaluation Checklist for Lifting, Carrying, Pushing, or Pulling
(Waters and Putz-Anderson, 1996)

Date/ Time 11/9/99 Facility Area/ Shop Structural Shop: Rakeframe assembly
Task Shipfitter

* "YES" responses are indicative of conditions that pose a risk of developing low back pain; the larger the percentage of "YES" responses, the greater the risk.

RISK FACTORS	YES	NO
General		
1.1 Does the load handled exceed 50 lbs?	Y (usually)	
1.2 Is the object difficult to bring close to the body because of it's size, bulk, or shape?	Y	
1.3 Is the load hard to handle because it lacks handles or cutouts for handles, or does it have slippery surfaces or sharp edges?	Y	
1.4 Is the footing unsafe? For example, are the floors slippery, inclined, or uneven?	Y (fixtures in way)	
1.5 Does the task require fast movement, such as throwing, swinging, or rapid walking?		N
1.6 Does the task require stressful body postures such as stooping to the floor, twisting, reaching overhead, or excessive lateral bending?	Y (extreme lumbar flexion)	
1.7 Is most of the load handled by only one hand, arm, or shoulder?		N
1.8 Does the task require working in environmental hazards, such as extreme temperatures, noise, vibration, lighting, or airborne contamination?	Y (welding, machinery in proximity,)	
1.9 Does the task require working in a confined area?		N
Specific		
2.1 Does the lifting frequency exceed 5 lifts per minute (LPM)?		N (LPM = 0.67 over total cycle time, but lifts are performed in rapid succession at a frequency of 2 LPM)
2.2 Does the vertical lifting distance exceed 3 feet?		N (seldom)
2.3 Do carries last longer than 1 minute?		N
2.4 Do tasks which require large sustained pushing or pulling forces exceed 30 seconds duration?		N (usually < = 10)
2.5 Do extended reach static holding tasks exceed 1 minute?		N
TOTAL	6 (43%)	8 (57%)

Table 5. Rake Frame Shipfitter 3D Static Strength Prediction Program

3D Static Strength Prediction Program
(University of Michigan, 1997)

Date/ Time: 11/9/99 Area/ Shop: Structural Shop, Rakeframe assembly
Facility: Task: Angle Set-Up by Shipfitter

Work Elements: Manual Placement of Angle Iron Rake Frame Components	**Disc Compression (lbs) @ L5/S1** (Note: NIOSH Recommended Compression Limit (RCL) is 770 lbs)
Angle RF2 weighs 133 lbs; lifts one end off stack pivots angle, then drops into place; 33.25 lbs per arm (frame #3960)	**1389** (middle of lift)
Curved angle RF1 weighs 246 lbs; lifts one end, pivots into place, lowers load with control; 123 lbs lifted, 61.5 lbs per arm (frames #4320, #4350)	**857** (middle of lift) **1531** (end of lift)
Angle RF3 weighs 125 lbs; lifts one end off stack, and pivots into place, lowers load, then drops into place; lifts @ 62.5 lbs or 31.25 lbs per arm (frames #6030, #6060, #6119)	**926** (beginning of lift) 597 (middle of lift) **1021** (end of lift)
Angle RF4 weighs 47 lbs; Shipfitter lifts one end with one hand; lifts 23.50 lbs by right arm (frame #7920), then lowers entire angle; lifts 23.50 lbs per arm (frame #7980)	**854** (beginning of lift) 691 (middle of lift)
Angle RT-3 weighs 65 lbs; lifts one end with one hand off stack; 32.50 lbs by right arm (frame #8550). Then, uses two arms to carry angle into place; 32.50 lbs per arm (frame #8700)	**1009** (beginning of lift) 551 (middle of lift)
Angle RT-1 weighs 95 lbs; lifts one end with one hand off stack before using two to drag it into place;47.50 lbs by right arm for initial lift (frame #9810)	**926** (beginning of lift)
Angle RT-2 weighs 70 lbs; lifts one end with one hand off stack before using two hands to drag it into place;35 lbs by right arm (frame #10980)	709 (beginning of lift)
Angle RF-5 weighs 52 lbs; lifts one end with both hands off stack before using two to lift it into place;26 lbs lifted per arm (frame #11150, 11700)	**1187** (beginning of lift) 668 (middle of lift)

Table 6. Rake Frame Shipfitter PLIBEL

PLIBEL Checklist
(Kemmlert, 1995)

Date/ Time: 11/9/99 Facility: Area/ Shop: Structural Shop : Rakeframe Assembly

Task: Shipfitter

Section I: Musculoskeletal Risk Factors

Methods of Application:

1) Find the injured body region, answer yes or no to corresponding questions (Preferred Method)
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	*Body Regions*				
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	Y	Y	Y	Y	Y
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	N				N
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? E.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	Y				Y
d) severely twisted?	Y				Y

Table 6 (continued). Rake Frame Shipfitter PLIBEL

10: Is repeated or sustained work performed when the neck is:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	Y				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Notice factors of importance as:					
a) periods of repetitive lifting	Y				Y
b) weight of load	Y				Y
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	Y				Y
e) handling beyond forearm length	Y				Y
f) handling below knee length	Y				Y
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	N				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		Y			
b) forceful movements?		Y			
c) uncomfortable hand positions?		N			
d) switches or keyboards?		N			

Table 6 (continued). Rake Frame Shipfitter PLIBEL

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
SUM	20	9	3	3	15
PERCENTAGE	76.9	81.8	37.5	37.5	71.4

Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores	
18: Is there no possibility to take breaks and pauses?	N
19: Is there no possibility to choose order and type of work tasks or pace of work?	Y
20: Is the job performed under time demands or psychological stress?	Y
21:Can the work have unusual or expected situations?	N
22: Are the following present?	
a) cold	N
b) heat	Y
c) draft	Y
d) noise	Y
e) troublesome visual conditions	Y
f) jerks, shakes, or vibration	N
Environmental / Organizational Risk Factors Score	
SUM	6
PERCENTAGE	60.0

B7.2. Rake Frame Welders

Table 7. Rake Frame Welders RULA

Rapid Upper Limb Assessment (RULA)
(Matamney and Corlett, 1993)

Date/ Time 11/9/99 Facility: Area/ Shop: Structural Shop
Task : Rakeframe assembly welding task

RULA Component	***Frame # 54600***		***Frame# 62130***		***Frame # 66600***		***Frame # 68580***		***Composite*** ***(of most common postures from frames 53820 -- 73290)***	
	Specific	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*
Shoulder Extension/ Flexion	*m flex*	*3*	*sl flex*	*2*	*sl flex*	*2*	*sl flex*	*2*	*sl flex (53%)*	*2*
Shoulder is Raised (+1)		*0*		*0*		*0*		*0*		*0*
Upper Arm Abducted (+1)		*0*		*0*		*0*		*0*		*0*
Arm supported, leaning (-1)		*-1*		*-1*		*-1*		*-1*		*-1*
Elbow Extension/ Flexion	*neut*	*2*	*ext*	*1*	*ext*	*1*	*flex*	*2*	*ext (61%)*	*1*
Shoulder Abduction/ Adduction	*add*	*1*	*add*	*1*	*add*	*1*	*mod abd*	*1*	*neut (50%)*	*0*
Shoulder Lateral/ Medial	*neut*	*0*	*m med*	*1*	*m med*	*1*	*m med*	*1*	*neut (51%)*	*0*
Wrist Extension/ Flexion	*ext*	*2*	*ext*	*2*	*ext*	*2*	*ext*	*2*	*ext (64%)*	*2*
Wrist Deviation [Wrist Bent from Midline (+1)]	*ulnar*	*1*	*rad*	*1*	*neut*	*0*	*ulnar*	*1*	*neut (33%)*	*0*
Wrist Bent from Midline (+1) (taken care of by deviation)		*0*		*0*		*0*		*0*		*0*
Wrist Twist (+1) In mid range (+2) End of range		*1*		*1*		*1*		*1*		*1*
Arm and Wrist Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		*1*		*1*		*1*		*1*		*1*
Arm and Wrist Force/ load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		*2*		*2*		*2*		*2*		*2*

Neck Extension/ Flexion		***3***		***3***		***3***		***3***		***3***
Neck Twist (+1)		***0***		***0***		***0***		***0***		***0***
Neck Side-Bent (+1)		***0***		***0***		***0***		***0***		***0***
Trunk Extension/ Flexion	***hyp flex***	***4***	***sl flex***	***2***	***hyp flex***	***4***	***hyp flex***	***4***	***hyp flex 100%***	***4***
Trunk Twist (+1)		***0***		***0***		***0***		***0***		***0***
Trunk Side Bend (+1)		***0***		***0***		***0***		***0***		***0***
Legs ***If legs and feet are supported and balanced: (+1); If not: (+2)***		***1***		***1***		***1***		***1***		***1***
Neck, Trunk, and Leg Muscle Use Score ***If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)***		***1***		***1***		***1***		***1***		***1***
Neck, Trunk, and Leg Force/ Load Score ***If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)***		***3***		***2***		***3***		***3***		***3***
Total RULA Score	*7*		*7*		*7*		*7*		*7*	

1 or 2 = Acceptable
3 or 4 = Investigate further
5 or 6 = Investigate further and change soon
7 = Investigate and change immediately

Table 8. Rake Frame Welder Strain Index

STRAIN INDEX: DISTAL UPPER EXTREMITY(DUE) DISORDERS RISK ASSESSMENT
(Moore and Garg, 1995)

LOCATION: Structural Shop DATE: 11/9/99 TASK: Rakeframe Welding

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Circle the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.					
Rating Criterion	***% MS (percentage of maximal strength)***	***Borg Scale (Compare to Borg Cr-10 Scale)***	***Perceived Effort***	***Rating (circle)***	***Multiplier***
Light	***< 10%***	***< or = 2***	***barely noticeable or relaxed effort***	***1***	***1***
Somewhat hard	***10 - 29%***	***3***	***noticeable or definite effort (84% of observed time)***	***2***	***3***
Hard	***30 - 49%***	***4 - 5***	***obvious effort; unchanged facial expression***	***3***	***6***
Very Hard	***50 - 79%***	***6 - 7***	***substantial effort; changes to facial expression***	***4***	***9***
Near Maximal	***> or = 80%***	***> 7***	***uses shoulder or trunk to generate force***	***5***	***13***
				Intensity of Exertion Multiplier (Fill in)	***3***

Table 8 (continued). Rake Frame Welders Strain Index

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
% Duration of Exertion	***< 10***	***1***	***0.5***
= 100 x duration of all exertions (sec) / Total observation time (sec)	***10 - 29***	***2***	***1.0***
	30 - 49	***3***	***1.5***
= 100 x 2365(sec)/ 3593 (sec)	***50 -79***	***4***	***2.0***
= 66 , but welding is very static	***> or = 80***	***5***	***3.0***
		Duration of Exertion Multiplier (Fill in)	***2.0***

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
Efforts per Minute	**< 4**	**1**	**0.5**
= 100 x number of exertions / Total observation time (min)	**4 - 8**	**2**	**1.0**
	9 -14	**3**	**1.5**
	15 -19	**4**	**2.0**
***welding is a very static task**	**> or = 20**	**5**	**3.0**
		Efforts per Minute Multiplier (Fill in)	**3.0**

Table 8 (continued). Rake Frame Welders Strain Index

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Circle the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	***Wrist Extension* (Stetson et al, 1991)**	***Wrist Flexion* (Stetson et al, 1991)**	***Ulnar Deviation* (Stetson et al, 1991)**	***Perceived Posture***	***Rating* (circle)**	***Multiplier***
Very Good	**0 -10 degrees**	**0 - 5 degrees**	**0 - 10 degrees**	**perfectly neutral**	**1**	**1.0**
Good	**11 - 25 degrees**	**6 - 15 degrees**	**11 -15 degrees**	**near neutral**	**2**	**1.0**
Fair	**26 -40 degrees (64% of observed time)**	**16 - 30 degrees (3% of observed time)**	**16 - 20 degrees (30% of observed time)**	**non-neutral**	**3**	**1.5**
Bad	**41 - 55 degrees**	**31 - 50 degrees**	**21 -25 degrees**	**marked deviation**	**4**	**2.0**
Very Bad	**> 60 degrees**	**> 50 degrees**	**> 25 degrees**	**near extreme**	**5**	**3.0**
					Hand/ Wrist Posture Multiplier (Fill in)	**1.5**

Table 8 (continued). Rake Frame Welders Strain Index

5. Speed of Work: An estimate of how fast the worker is working. Circle the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	***Compared to MTM* -1 (observed pace is divided by MTM's predicted pace and expressed as %; See Barnes 1980)**	***Perceived Speed***	***Rating* (circle)**	***Multiplier***
Very Slow	**< or = 80%**	**extremely relaxed pace**	**1**	**1.0**
Slow	**81 - 90%**	**"taking one's own time"**	**2**	**1.0**
Fair	**91 -100%**	**"normal" speed of motion**	**3**	**1.0**
Fast	**101-115%**	**rushed, but able to keep up**	**4**	**1.5**
Very Fast	**> 115%**	**rushed and barely or unable to keep up**	**5**	**2.0**
			Speed of Work Multiplier (Fill in)	**1.0**

6. Duration of Task per Day: Either measured or obtained from plant personnel. Circle the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
Duration of Task per Day (hrs)	**< or = 1 hrs**	**1**	**0.25**
= duration of task (hrs) + duration of task (hrs) + ...	**1 - 2 hrs**	**2**	**0.50**
	2 - 4 hrs	**3**	**0.75**
= (22 frames per day @ 20 minutes per frame- - from mgmt-- 7.3 hrs of frame cycle time @ .68 duration of exertion (See #2) = 4 hrs per day)	**4 - 8 hrs**	**4**	**1.00**
	> or = 8 hrs	**5**	**1.50**
		Duration of Task per Day Multiplier (Fill in)	**1.0**

Table 8 (continued). Rake Frame Welders Strain Index

Calculate the Strain Index (SI) Score: **Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.**							
Intensity of Exertion **3 x**	**Duration of Exertion** **2 x**	**Efforts per Minute** **3 x**	**Hand/ Wrist Posture** **1.5 x**	**Speed of Work** **1 x**	**Duration of Task** **1**	**=**	**SI SCORE 27**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:

– SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
– SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
– SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
– SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 9. Rake Frame Welder UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
(Lifshitz and Armstrong, 1986)

Date/ Time 11/9/99 Facility Area/ Shop Structural Shop : Rakeframe assembly
Task Welder
* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	**No**	**Yes**
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges?		Y
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?		Y
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?		Y
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?		Y

5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N (static)	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?		Y
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?		Y (handle)
6.3 Is the handle of the tool made from material other than metal?		Y
6.4 Is the weight of the tool below 4 kg (9 lbs)?		Y (@ 5.5 lbs)
6.5 Is the tool suspended?	N	
TOTAL	10	12

Table 10. Rake Frame Welder OWAS

OWAS: OVAKO Work Analysis System
(Louhevaara and Suurnäkki, 1992)

Procedure: Observe workers at intervals of 30-60 seconds and record the postures and forces over a representative period (~ 45 minutes)

Date/ Time 11/9/99 Facility Area/ Shop Structural Shop : Rakeframe assembly
Task Welder

Risk Factor	Work Phase 1 welding inside frame at pos. 1	Work Phase 2 welding straddle frame at pos. 1	Work Phase 3 de-slagging	Work Phase 4 welding outside frame at pos.2	Work Phase 5 un-defined	Work Phase 6 resting	Work Phase 7 guiding crane lowering frame	Work Phase 8	Work Phase 9
TOTAL Combination Posture Score	*2*	*2*	*2*	*2*	*1*	*1*	*1*		
Common Posture Combinations (collapsed across work phases)									
Back	2	1	2	2	1				
Arms	1	1	1	1	1				
Legs	1	7	7	4	1				
Posture Repetition (% of working time)	16	8	3	55	29				
BACK % of Working Time SCORE	*2*	*1*	*1*	*2*	*1*				
ARMS % of Working Time SCORE	*1*	*1*	*1*	*1*	*1*				
LEGS % of Working Time SCORE	*1*	*1*	*1*	*3*	*1*				

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Risk Factor	Work Phase1 welding inside frame at pos. 1	Work Phase 2 welding straddle frame at pos. 1	Work Phase 3 de-slagging	Work Phase 4 welding outside frame at pos.2	Work Phase 5 un-defined	Work Phase 6 resting	Work Phase 7 guiding crane lowering frame	Work Phase 8	Work Phase 9
Posture									
Back **1 = straight**	2	2	2	2	1	1	1		

2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways									
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1	1	1	1		
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	1, 4	1, 4	7	4	7	1	7		
Load/ Use of Force									
1 = weight or force needed is = or <10 kg (<22lbs)	1	1	1	1	1	1	1		
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)									
3 = weight or force > 20 kg (>44 lbs)									
Phase Repetition									
% of working time (0,10,20,30,40,50,60,70,80,90,100)	31	10	3	19	5	29	3		

Table 10 (continued). Rake Frame Welder OWAS

Table 11. Rake Frame Welder PLIBEL

PLIBEL Checklist
(Kemmlert, 1995)

Date/ Time: 11/9/99 Facility Area/ Shop: Structural Shop : Rakeframe assembly
Task: Welder

Section I: Musculoskeletal Risk Factors

Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions (Preferred Method)
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	*Body Regions*				
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	N	N	N	N	N
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? E.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 11 (continued). Rake Frame Welder PLIBEL

10: Is repeated or sustained work performed when the neck is:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	Y				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Notice factors of importance as:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	N				N
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	N				N
f) handling below knee length	N				N
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	Y				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		N			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 11 (continued). Rake Frame Welder PLIBEL

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
SUM	13	6	1	1	6
PERCENTAGE	50.0	54.5	12.5	12.5	28.6

Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores	
18: Is there no possibility to take breaks and pauses?	N
19: Is there no possibility to choose order and type of work tasks or pace of work?	Y
20: Is the job performed under time demands or psychological stress	Y
21:Can the work have unusual or expected situations?	N
22: Are the following present?	
a) cold	N
b) heat	Y
c) draft	Y
d) noise	Y
e) troublesome visual conditions	Y
f) jerks, shakes, or vibration	N
Environmental / Organizational Risk Factors Score	
SUM	6
PERCENTAGE	60.0

B7.3. Gator Bar Worker in Steelyard

Table 12. Gator Bar Worker RULA

Rapid Upper Limb Assessment (RULA)
(Matamney and Corlett, 1993)

Date/ Time 11/9/99 Facility Area/ Shop: Steelyard
Task : Angle iron separation by gator bar worker

RULA Component	*Frame # 25650*		*Frame # 26310*		*Frame # 27060*		*Frame # 27510*		*Composite* *(of most common postures from frames 24660 - 27330)*	
	Specific	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***
Shoulder Extension/ Flexion	*sl flex*	*2*	*sl flex*	*2*	*mod flex*	*3*	*sl flex*	*2*	*sl flex (68%)*	*2*
Shoulder is Raised (+1)		*0*		*1*		*1*		*1*		*1*
Upper Arm Abducted (+1)		*0*		*0*		*0*		*0*		*0*
Arm supported, leaning (-1)		*0*		*0*		*0*		*0*		*0*
Elbow Extension/ Flexion	*flex*	*2*	*ext*	*1*	*flex*	*2*	*ext*	*1*	*flex (41%)*	*2*
Shoulder Abduction/ Adduction	*m abd*	*1*	*neut*	*0*	*m abd*	*1*	*m abd*	*1*	*neut (59%)*	*0*
Shoulder Lateral/ Medial	*m med*	*1*	*neut*	*0*	*lat*	*1*	*m med*	*1*	*neut (47%)*	*0*
Wrist Extension/ Flexion	*ext*	*2*	*ext*	*2*	*ext*	*2*	*ext*	*2*	*ext (62%)*	*2*
Wrist Deviation	*ulnar*	*1*	*ulnar*	*1*	*rad*	*1*	*ulnar*	*1*	*ulnar (53%)*	*1*
Wrist Bent from Midline (+1)		*0*		*0*		*0*		*0*		*0*
Wrist Twist (1) In mid range ***Or*** *(2) End of range*		*1*		*1*		*1*		*1*		*1*
Arm and Wrist Muscle Use Score *If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)*		*1*		*1*		*1*		*1*		*1*
Arm and Wrist Force/ load Score *If load less than 2 kg (intermittent): (+0)* *If 2kg to 10 kg (intermittent): (+1)* *If 2kg to 10 kg (static or repeated): (+2)* *If more than 10 kg load or repeated or shocks: (+3)*		*3*		*3*		*3*		*3*		*3*
Neck Extension/ Flexion		*2*		*2*		*2*		*2*		*2*
Neck Twist (+1)		*1*		*0*		*1*		*0*		*0*

Neck Side-Bent (+1)		*0*		*0*		*0*		*0*		*0*
Trunk Extension/ Flexion	*sl flex*	*2*	*sl flex*	*2*	*sl flex*	*2*	*sl flex*	*2*	*sl flex (64%)*	*2*
Trunk Twist (+1)		*1*		*0*		*1*		*0*		*0*
Trunk Side Bend (+1)		*0*		*0*		*0*		*0*		*0*
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		*1*		*1*		*1*		*1*		*1*
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e., held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		*1*		*1*		*1*		*1*		*1*
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		*3*		*3*		*3*		*3*		*3*
Total RULA Score	***7***		***7***		***7***		***7***		***7***	
1 or 2 = ACCEPTABLE 3 or 4 = INVESTIGATE FURTHER 5 or 6 = INVESTIGATE FURTHER AND CHANGE SOON 7 = INVESTIGATE AND CHANGE IMMEDIATELY										

Table 12 (continued). Gator Bar Worker RULA

Table 13. Gator Bar Worker Strain Index

STRAIN INDEX: DISTAL UPPER EXTREMITY(DUE) DISORDERS RISK ASSESSMENT
(Moore and Garg, 1995)

LOCATION: Steelyard, 11/9/99 TASK: Angle Iron Separation

Intensity of Exertion: *An estimate of the strength required to perform the task one time. Circle the rating after using e guidelines below, then fill in the corresponding multiplier in the bottom far right box.*

ating riterion	***% MS*** *(percentage of maximal strength)*	***Borg Scale*** *(Compare to Borg Cr-10 Scale)*	***Perceived Effort***	***Rating*** *(circle)*	***Multiplier***
ight	*< 10%*	*< or = 2*	*barely noticeable or relaxed effort*	*1*	*1*
omewhat ard	*10 - 29%*	*3*	*noticeable or definite effort*	*2*	*3*
ard	*30 - 49%*	*4 - 5*	*obvious effort; unchanged facial expression*	*3*	*6*
ery Hard	***50 - 79%***	***6 - 7***	***substantial effort; changes to facial expression (*68% of observed time > or = very hard)***	***4***	***9***
ear laximal	*> or = 80%*	*> 7*	*uses shoulder or trunk to generate force*	*5*	*13*
				Intensity of Exertion Multiplier (Fill in)	***9***

Table 13 (continued). Gator Bar Worker Strain Index

2. ***Duration of Exertion (% of cycle)****: Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.* ****NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0***

Worksheet:	*Rating Criterion*	*Rating*	*Multiplier*
% Duration of Exertion	*< 10*	*1*	*0.5*
= 100 x duration of all exertions (sec) / Total observation time (sec)	***10 - 29***	***2***	***1.0***
	30 - 49	*3*	*1.5*
= 100 x 9.08 (min)/ 44.38(min) = 20	*50 -79*	*4*	*2.0*
for task "loading conveyor (gator picking, hooking)***"*	*> or = 80*	*5*	*3.0*
	Duration of Exertion Multiplier *(Fill in)*		***1.0***

3. ***Efforts per Minute:*** *Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.* ****NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0***

Worksheet:	*Rating Criterion*	*Rating*	*Multiplier*
Efforts per Minute	*< 4*	*1*	*0.5*
= 100 x number of exertions / Total observation time (min)	*4 - 8*	*2*	*1.0*
	9 -14	***3***	***1.5***
= 100 x [total # of efforts for observed period, 546/ Total observed time (min) 44.38]	*15 -19*	*4*	*2.0*
= 12.30	*> or = 20*	*5*	*3.0*
	Efforts per Minute Multiplier *(Fill in)*		***1.5***

Table 13 (continued). Gator Bar Worker Strain Index

Hand/ Wrist Posture: *An estimate of the position of the hand or wrist relative to neutral position. Circle the rating fter using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.*

ating riterion	***Wrist Extension*** *(Stetson et al, 1991)*	***Wrist Flexion*** *(Stetson et al, 1991)*	***Ulnar Deviation*** *(Stetson et al, 1991)*	***Perceived Posture***	***Rating*** *(circle)*	***Multiplier***
ery ood	*0 -10 degrees*	*0 - 5 degrees*	*0 - 10 degrees*	*perfectly neutral*	*1*	*1.0*
ood	*11 - 25 degrees*	*6 - 15 degrees*	*11 -15 degrees*	*near neutral*	*2*	*1.0*
air	*26 -40 degrees*	*16 - 30 degrees*	*16 - 20 degrees*	*non-neutral*	*3*	*1.5*
ad	***41 - 55 degrees (extension 52% of load task time)***	***31 - 50 degrees (flexion 11% of load task time)***	***21 -25 degrees (ulnar deviation 53% of load task time)***	***marked deviation***	***4***	***2.0***
ery Bad	*> 60 degrees*	*> 50 degrees*	*> 25 degrees*	*near extreme*	*5*	*3.0*
				Hand/ Wrist Posture Multiplier *(Fill in)*		***2.0***

Table 13 (continued). Gator Bar Worker Strain Index

5. **Speed of Work:** *An estimate of how fast the worker is working. Circle the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.*				
Rating Criterion	***Compared to MTM -1*** *(observed pace is divided by MTM's predicted pace and expressed as %; See Barnes 1980)*	***Perceived Speed***	***Rating*** *(circle)*	***Multiplier***
Very Slow	*< or = 80%*	*extremely relaxed pace*	*1*	*1.0*
Slow	*81 - 90%*	*"taking one's own time"*	*2*	*1.0*
Fair	***91 -100%***	***"normal" speed of motion***	***3***	***1.0***
Fast	*101-115%*	*rushed, but able to keep up*	*4*	*1.5*
Very Fast	*> 115%*	*rushed and barely or unable to keep up*	*5*	*2.0*
Speed of Work Multiplier *(Fill in)*				***1.0***

6. **Duration of Task per Day:** *Either measured or obtained from plant personnel. Circle the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.*			
Worksheet: *Duration of Task per Day (hrs)* *= duration of task (hrs) + duration of task (hrs) + ...* *= (works 8 hrs at 20%, see # 2, therefore duration is ~ 1-2 hrs per day*	***Rating Criterion***	***Rating*** *(circle)*	***Multiplier***
	< or = 1 hrs	*1*	*0.25*
	1 - 2 hrs	***2***	***0.50***
	2 - 4 hrs	*3*	*0.75*
	4 - 8 hrs	*4*	*1.00*
	> or = 8 hrs	*5*	*1.50*
Duration of Task per Day Multiplier (Fill in)			***0.50***

Table 13 (continued). Gator Bar Worker Strain Index

Calculate the Strain Index (SI) Score*: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.*							
Intensity of Exertion ***9*** **x**	***Duration of Exertion*** ***1*** **x**	***Efforts per Minute*** ***1.5*** **x**	***Hand/ Wrist Posture*** ***2*** **x**	***Speed of Work*** ***1*** **x**	***Duration of Task*** ***.50***	**=**	***SI SCORE*** ***13.5***

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:

– SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
– SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
– SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
– SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 14. Gator Bar Worker UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
(Lifshitz and Armstrong, 1986)

Date/ Time 11/9/99 Facility Area/ Shop Steelyard: Angle Iron Separation
Task: Gator Bar Worker
* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	***No***	***Yes***
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges	*N*	
1.2 Is the tool operating without vibration?		*Y*
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	*N*	*Y*
1.4 Can the job be done without using gloves?	*N*	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	*N*	
2.2 Can the job be done without using finger pinch grip?		*Y*
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	*N*	
3.2 Can the tool be used without flexion or extension of the wrist?	*N*	
3.3 Can the job be done without deviating the wrist from side to side?	*N*	
3.4 Can the tool be used without deviating the wrist from side to side?	*N*	
3.5 Can the worker be seated while performing the job?	*N*	
3.6 Can the job be done without "clothes wringing" motion?		*Y*
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	*N*	
4.2 Can the height of the work surface be adjusted?	*N*	
4.3 Can the location of the tool be adjusted?	*N*	

5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?		*Y*
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?		*Y*
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	*Not measured*	*Not measured*
6.3 Is the handle of the tool made from material other than metal?	*N*	
6.4 Is the weight of the tool below 4 kg (9lbs)?	*N (12.2lbs)*	
6.5 Is the tool suspended?	*N*	
TOTAL	*15 (71%)*	*6 (29%)*

Table 15. Gator Bar Worker OWAS

OWAS: OVAKO Work Analysis System
(Louhevaara and Suurnäkki, 1992)

Procedure: Observe workers at intervals of 30-60 seconds and record the postures and forces over a representative period (~ 45 minutes)

Date/ Time 11/9/99 Facility Area/ Shop: Steelyard
Task: Gator Bar Worker

	Work Phase1: **Waiting for Crane**	***Work Phase 2*** **Crane lowering load**	***Work Phase 3*** **Unstrap-ping load (and cutting binding)**	***Work Phase 4*** **Using pry end of bar to separate angles**	***Work Phase 5*** **Using pry end to lever angle over**	***Work Phase 6*** **Using jaw end of bar to separate angles**	***Work Phase 7*** **Using jaw end to flip angle over**	***Work Phase 8*** **Move load off conveyor**	***Work Phase 9*** **Crane removes excess angles**
TOTAL Combination Posture Score	***1***	***1***	***1***	***4***	***4***	***4***	***2***	***1***	***1***
Common Posture Combinations (collapsed across work phases)									
Back	1	2	2	1					
Arms	1	3	3	3					
Legs	2	2	7	2					
Posture Repetition (% of working time)	42	19	19	1					
BACK % of Working Time SCORE	***1***	***3***	***4***	***1***					
ARMS % of Working Time SCORE	***1***	***1***	***1***	***1***					
LEGS % of Working Time SCORE	***1***	***1***	***1***	***1***					

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Risk Factor	**Work Phase 1** **Waiting for Crane**	***Work Phase 2*** **Crane lowering load**	***Work Phase 3*** **Unstrap-ping load (and cutting binding)**	***Work Phase 4*** **Using pry end of bar to separate angles**	***Work Phase 5*** **Using pry end to lever angle over**	***Work Phase 6*** **Using jaw end of bar to separate angles**	***Work Phase 7*** **Using jaw end to flip angle over**	***Work Phase 8*** **Move load off conveyor**	***Work Phase 9*** **Crane removes excess angles**

Posture									
Back *1 = straight* *2 = bent forward, backward* *3 = twisted or bent sideways* *4 = bent and twisted or bent forward and sideways*	*1*	*1*	*1*	*2*	*2*	*2*	*1**	*1*	*1*
Arms *1 = both arms are below shoulder level* *2 = one arm is at or above shoulder level* *3 = both arms are at or above shoulder level*	*1*	*1*	*3*	*3*	*3*	*3*	*3*	*1*	*1*
Legs *1 = sitting* *2 = standing with both legs straight* *3 = standing with the weight on one straight leg* *4 = standing or squatting with both knees bent* *5 = standing or squatting with one knee bent* *6 = kneeling on one or both knees* *7 = walking or moving*	*2*	*2*	*2,7*	*2,7*	*2,7*	*2,7*	*2,7*	*2*	*2*
Load/ Use of Force									
1 = weight or force needed is = or <10 kg *2 = weight or force > 10 but < 20kg* *3 = weight or force > 20 kg*	*1*	*1*	*1*	*3**	*3**	*3**	*3**	*1*	*1*
Phase Repetition									
% of working time (0,10,20,30,40,50,60,70,80,90,100)	*16*	*5*	*11*	*07*	*07*	*05*	*01*	*20*	*01*

Table 16. Gator Bar Worker PLIBEL

PLIBEL Checklist
(Kemmlert, 1995)

Date/ Time: 11/9/99 Facility: Area/ Shop: Steelyard, Angle Iron Separation
Task: Gator Bar Worker

Section I: Musculoskeletal Risk Factors

Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions (Preferred Method)
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	*Body Regions*				
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			Y	Y	Y
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? E.g. ...					
a) repeated stepping up on stool, step etc..?			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	Y				Y
d) severely twisted?	Y				Y

Table 16 (continued). Gator Bar Worker PLIBEL

10: Is repeated or sustained work performed when the neck is:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	Y				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Notice factors of importance as:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	N				N
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	Y				Y
f) handling below knee length	N				N
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	N				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		Y			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 16 (continued). Gator Bar Worker PLIBEL

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
SUM	15	9	3	3	11
PERCENTAGE	57.7	81.8	37.5	37.5	52.4
Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	Y				
20: Is the job performed under time demands or psychological stress?	Y				
21:Can the work have unusual or expected situations?	Y				
22: Are the following present?					
a) cold	Y				
b) heat	Y				
c) draft	Y				
d) noise	Y				
e) troublesome visual conditions	N				
f) jerks, shakes, or vibration	Y				
Environmental / Organizational Risk Factors Score					
SUM	8				
PERCENTAGE	80.0				

B4. Steelyard Helper

Table 17. Steelyard Helper RULA

Rapid Upper Limb Assessment (RULA)
(Matamney and Corlett, 1993)

Date/ Time 11/9/99______ Facility: ________________ Area/ Shop: Steelyard
Task : Flip and drag angle iron across roller conveyor

RULA Component	**Frame # 25200**		**Frame# 25590**		**Frame # 25920**		**Frame # 26610**		**Composite** *(of most common postures from frames 24660 - 27630)*	
	Specific	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*
Shoulder Extension/ Flexion	**mod flex**	**3**	**mod flex**	**3**	**hyp flex**	**4**	**sl flex**	**2**	**sl flex (35%)**	**2**
Shoulder is Raised (+1)		**0**		**0**		**1**		**0**		**0**
Upper Arm Abducted (+1)		**0**		**1**		**0**		**1**		**1**
Arm supported, leaning (-1)		**0**		**0**		**0**		**0**		**0**
Elbow Extension/ Flexion	**neut**	**2**	**ext**	**1**	**neut**	**2**	**ext**	**1**	**ext (60%)**	**1**
Shoulder Abduction/ Adduction	**add**	**1**	**m abd**	**1**	**add**	**1**	**neut**	**0**	**m abd (36%)**	**1**
Shoulder Lateral/ Medial	**m med**	**1**	**lat**	**1**	**m med**	**1**	**lat**	**1**	**lat (45%)**	**1**
Wrist Extension/ Flexion	**ext**	**2**	**ext**	**2**	**ext**	**2**	**flex**	**2**	**flex (49%)**	**2**
Wrist Deviation	**ulnar**	**1**	**ulnar**	**1**	**rad**	**1**	**ulnar**	**1**	**ulnar (45%)**	**1**
Wrist Bent from Midline (+1)		**0**		**0**		**0**		**0**		**0**
Wrist Twist (+1) In mid range (+2) End of range		**1**		**1**		**1**		**1**		**1**
Arm and Wrist Muscle Use Score. If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		**1**		**1**		**1**		**1**		**1**
Arm and Wrist Force/ load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		**2**		**2**		**2**		**2**		**2**
Neck Extension/ Flexion		**2**		**2**		**2**		**1**		**2**
Neck Twist (+1)		**1**		**1**		**0**		**1**		**1**
Neck Side-Bent (+1)		**0**		**0**		**0**		**0**		**0**

Trunk Extension/ Flexion	**sl flex**	**2**	**sl flex**	**2**	**sl flex**	**2**	**neut**	**1**	**sl flex (50%)**	**2**
Trunk Twist (+1)		**1**		**0**		**0**		**0**		**0**
Trunk Side Bend (+1)		**1**		**0**		**0**		**0**		**0**
Legs **If legs and feet are supported and balanced: (+1);** **If not: (+2)**		**1**		**1**		**1**		**1**		**1**
Neck, Trunk, and Leg Muscle Use Score **If posture mainly static (i.e., held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)**		**1**		**1**		**1**		**1**		**1**
Neck, Trunk, and Leg Force/ Load Score **If load less than 2 kg (intermittent): (+0)** **If 2kg to 10 kg (intermittent): (+1)** **If 2kg to 10 kg (static or repeated): (+2)** **If more than 10 kg load or repeated or shocks: (+3)**		**2**		**2**		**2**		**2**		**2**
Total RULA Score	**7**		**7**		**7**		**6**		**7**	

1 or 2 = ACCEPTABLE
3 or 4 = INVESTIGATE FURTHER
5 or 6 = INVESTIGATE FURTHER AND CHANGE SOON
7 = INVESTIGATE AND CHANGE IMMEDIATELY

Table 18. Steelyard Helper Strain Index

STRAIN INDEX: DISTAL UPPER EXTREMITY(DUE) DISORDERS RISK ASSESSMENT
(Moore and Garg, 1995)

LOCATION: Steelyard DATE: 11/9/99
TASK: Angle Iron Flip and Pull across Conveyor

Intensity of Exertion: An estimate of the strength required to perform the task one time. Circle the rating after using e guidelines below, then fill in the corresponding multiplier in the bottom far right box.

ating riterion	***% MS*** (percentage of maximal strength)	***Borg Scale*** (Compare to Borg Cr-10 Scale)	***Perceived Effort***	***Rating*** (circle)	***Multiplier***
ight	< 10%	< or = 2	barely noticeable or relaxed effort	1	1
omewhat ard	**10 - 29%**	**3**	**noticeable or definite effort (*76% of observed effort time)**	**2**	**3**
ard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6
ery Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9
ear laximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13
				Intensity of Exertion Multiplier (Fill in)	**3**

Table 18 (continued). Steelyard Helper Strain Index

2. **Duration of Exertion (% of cycle)**: Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.***NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0**

Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
% Duration of Exertion	< 10	1	0.5
= 100 x duration of all exertions (sec) / Total observation time (sec)	10 - 29	2	1.0
	30 - 49	**3**	**1.5**
= 100 x 13.62 (min)/ 44.38(min) = 31	50 -79	4	2.0
*for task "**loading conveyor (gator picking, hooking)**"	> or = 80	5	3.0
	Duration of Exertion Multiplier (Fill in)		**1.5**

3. **Efforts per Minute:** Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. ***NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0**

Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
Efforts per Minute	< 4	1	0.5
= 100 x number of exertions / Total observation time (min)	4 - 8	2	1.0
	9 -14	**3**	**1.5**
= 100 x [total # of efforts for observed period, 546/ Total observed time (min) 44.38]	15 -19	4	2.0
= 12.30	> or = 20	5	3.0
	Efforts per Minute Multiplier (Fill in)		**1.5**

Table 18 (continued). Steelyard Helper Strain Index

. **Hand/ Wrist Posture:** An estimate of the position of the hand or wrist relative to neutral position. Circle the rating ﬁter using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
ating riterion	***Wrist Extension*** (Stetson et al, 1991)	***Wrist Flexion*** (Stetson et al,1991)	***Ulnar Deviation*** (Stetson et al, 1991)	***Perceived Posture***	***Rating*** (circle)	***Multiplier***
ery ood	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
ood	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
air	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral	3	1.5
ad	**41 - 55 degrees (extension 13% of load task time)**	**31 - 50 degrees (flexion 49% of load task time)**	**21 -25 degrees (ulnar deviation 45% of load task time)**	**marked deviation**	**4**	**2.0**
ery Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
					Hand/ Wrist Posture Multiplier (Fill in)	**2.0**

Table 18 (continued). Steelyard Helper Strain Index

5. **Speed of Work:** An estimate of how fast the worker is working. Circle the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	***Compared to MTM*** -1 (observed pace is divided by MTM's predicted pace and expressed as %; See Barnes 1980)	***Perceived Speed***	***Rating*** (circle)	***Multiplier***
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	**91 -100%**	**"normal" speed of motion**	**3**	**1.0**
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed and barely or unable to keep up	5	2.0
Speed of Work Multiplier (Fill in)				**1.0**

6. **Duration of Task per Day:** Either measured or obtained from plant personnel. Circle the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet: Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (works 8 hrs at 31%, see # 2, therefore duration is ~ 2.4 hrs per day	***Rating Criterion***	***Rating*** (circle)	***Multiplier***
	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	**3**	**0.75**
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier (Fill in)			**.75**

Table 18 (continued). Steelyard Helper Strain Index

Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion **3 x**	**Duration of Exertion** **1.5 x**	**Efforts per Minute** **1.5 x**	**Hand/ Wrist Posture** **2 x**	**Speed of Work** **1 x**	**Duration of Task** **.75**	**=**	**SI SCORE** **10.1**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:

– SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
– SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
– SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;

– SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 19. Steelyard Helper UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
(Lifshitz and Armstrong, 1986)

Date/ Time 11/9/99 Facility Area/ Shop Steelyard: Angle Iron Flip and Pull
Task: Steelyard Helper
* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	**No**	**Yes**
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges?	**N**	
1.2 Is the tool operating without vibration?		**Y**
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	**N**	**Y**
1.4 Can the job be done without using gloves?		**Y**
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	**N**	
2.2 Can the job be done without using finger pinch grip?		**Y**
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	**N**	
3.2 Can the tool be used without flexion or extension of the wrist?	**N**	
3.3 Can the job be done without deviating the wrist from side to side?	**N**	
3.4 Can the tool be used without deviating the wrist from side to side?	**N**	
3.5 Can the worker be seated while performing the job?	**N**	
3.6 Can the job be done without "clothes wringing" motion?		**Y**
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	**N**	
4.2 Can the height of the work surface be adjusted?	**N**	
4.3 Can the location of the tool be adjusted?	**N**	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?		**N**
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?		**Y**
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	**Not measured**	**Not measured**
6.3 Is the handle of the tool made from material other than metal?	**N**	
6.4 Is the weight of the tool below 4 kg (9lbs)?	**N (12.2lbs)**	
6.5 Is the tool suspended?	**N**	
TOTAL	**14 (67%)**	**7 (33%)**

Table 20. Gator Bar Worker OWAS

OWAS: OVAKO Work Analysis System
(Louhevaara and Suurnäkki, 1992)

Procedure: Observe workers at intervals of 30-60 seconds and record the postures and forces over a representative period (~ 45 minutes)

Date/ Time 11/9/99 Area/ Shop: Steelyard
Task: Gator Bar Worker

	Work Phase 1 **Waiting for Crane**	**Work Phase 2** **Crane lowering load**	**Work Phase 3** **Unstrap-ping load (and cutting binding)**	**Work Phase 4** **Using jaw end of bar to flip angle over on table**	**Work Phase 5** **Dragging angle across table with hand**	**Work Phase 6** **Standing, waiting**			
TOTAL Combination Posture Score	***1***	***1***	***1***	***3***	***2 , 3***	***1***			
Common Posture Combinations (collapsed across work phases)									
Back	1	1	2, 4	2, 4					
Arms	1	3	3	1					
Legs	2	2, 7	2, 7	2, 7					
Posture Repetition (% of working time)	21	11	8	1					
BACK % of Working Time SCORE	***1***	***1***	***3, 3***	***2, 3***					
ARMS % of Working Time SCORE	***1***	***1***	***1***	***1***					
LEGS % of Working Time SCORE	***1***	***1***	***1***	***1***					
ACTION CATEGORIES: 1 = no corrective measures 2 = corrective measures in the near future 3 = corrective measures as soon as possible 4 = corrective measures immediately									
Risk Factor	**Work Phase 1**	**Work Phase 2**	**Work Phase 3**	**Work Phase 4**	**Work Phase 5**	**Work Phase 6**			

	Waiting for Crane	Crane lowering load	Unstrap-ping load (and cutting binding)	Using jaw end of bar to flip angle over on table	Dragging angle across table with hand	Standing, waiting			
Posture									
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	1	1	1	2,4	2,4	1			
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	3	3	1	1			
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	2	2	2,7	2,7	2,7	2,7			
Load/ Use of Force									
1 = weight or force needed is = or <10 kg 2 = weight or force > 10 but < 20kg 3 = weight or force > 20 kg	1	1	1	2	2	2			
Phase Repetition									
% of working time (0,10,20,30,40,50,60, 70,80,90,100)	16	5	11	08	22	01			

Table 20 (continued). Steelyard Helper OWAS

Table 21. Steelyard Helper PLIBEL

PLIBEL Checklist
(Kemmlert, 1995)

Date/ Time: 11/9/99 Area/ Shop: Steelyard, Angle Iron Flip and Pull
Task: Steelyard Helper

Section I: Musculoskeletal Risk Factors

Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions (Preferred Method)
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	*Body Regions*				
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	N				N
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? E.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	Y				Y
d) severely twisted?	N				N

Table 21 (continued). Steelyard Helper PLIBEL

10: Is repeated or sustained work performed when the neck is:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	Y				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Notice factors of importance as:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	N				N
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	N				N
f) handling below knee length	N				N
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	N				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	N	N			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		Y			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 21 (continued). Steelyard Helper PLIBEL

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
SUM	11	8	2	2	7
PERCENTAGE	42.3	72.7	25.0	25.0	33.3

Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores	
18: Is there no possibility to take breaks and pauses?	N
19: Is there no possibility to choose order and type of work tasks or pace of work?	Y
20: Is the job performed under time demands or psychological stress?	Y
21:Can the work have unusual or expected situations?	N
22: Are the following present?	
a) cold	Y
b) heat	Y
c) draft	Y
d) noise	Y
e) troublesome visual conditions	N
f) jerks, shakes, or vibration	N

Environmental / Organizational Risk Factors Score	
SUM	6
PERCENTAGE	60.0

B7.4. Honeycomb Welder

Table 22. Honeycomb Welder RULA

Rapid Upper Limb Assessment (RULA)
(Matamney and Corlett, 1993)

Date/ Time 11/9/99 Area/ Shop: Weld School
Task : Simulated Honeycomb Welding Task

RULA Component	**Frame # 1140**		**Frame # 6900**		**Frame # 10110**		**Frame # 12450**		**Composite** *(of most common postures from frames 24660 - 27630)*	
	Specific	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*
Shoulder Extension/ Flexion	sl flex	2	hyp flex	4	sl flex	2	sl flex	2	sl flex (78%)	2
Shoulder is Raised (+1)		1		0		0		0		0
Upper Arm Abducted (+1)		1		0		0		0		0
Arm supported, leaning (-1)		0		0		-1		0		0
Elbow Extension/ Flexion	flex	2	neut	2	flex	2	flex	2	flex (75%)	2
Shoulder Abduction/ Adduction	m abd	1	neut	0	add	1	add	1	add (35%)	1
Shoulder Lateral/ Medial	m med	1	m med	1	m med	1	m med	1	m med (83%)	1
Wrist Extension/ Flexion	ext	2	ext	2	ext	2	ext	2	ext (37%)	2
Wrist Deviation [Wrist Bent from Midline (+1)]	ulnar	1	ulnar	1	ulnar	1	ulnar	1	ulnar (51%)	1
Wrist Bent from Midline (+1) (taken care of by deviation)		0		0		0		0		0
Wrist Twist (+1) In mid range (+2) End of range		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		1		1		1
Arm and Wrist Force/ load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		2		2		2		2
Neck Extension/ Flexion		3		3		3		3		3
Neck Twist (+1)		1		1		0		0		1

Neck Side-Bent (+1)		**1**		**0**		**0**		**0**		**0**
Trunk Extension/ Flexion	**hyp flex**	**4**	**hyp flex**	**4**	**hyp flex**	**4**	**hyp flex**	**4**	**hyp flex 100%**	**4**
Trunk Twist (+1)		**1**		**0**		**0**		**0**		**0**
Trunk Side Bend (+1)		**1**		**0**		**0**		**0**		**0**
Legs **If legs and feet are supported and balanced: (+1);** **If not: (+2)**		**1**		**1**		**1**		**1**		**1**
Neck, Trunk, and Leg Muscle Use Score **If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)**		**1**		**1**		**1**		**1**		**1**
Neck, Trunk, and Leg Force/ Load Score **If load less than 2 kg (intermittent): (+0)** **If 2kg to 10 kg (intermittent): (+1)** **If 2kg to 10 kg (static or repeated): (+2)** **If more than 10 kg load or repeated or shocks: (+3)**		**2**		**2**		**2**		**2**		**2**
Total RULA Score	**7**		**7**		**7**		**7**		**7**	
1 or 2 = ACCEPTABLE **3 or 4 = INVESTIGATE FURTHER** **5 or 6 = INVESTIGATE FURTHER AND CHANGE SOON** **7 = INVESTIGATE AND CHANGE IMMEDIATELY**										

Table 22 (continued). Honeycomb Welder RULA

Table 23. Honeycomb Welder Strain Index

STRAIN INDEX: DISTAL UPPER EXTREMITY(DUE) DISORDERS RISK ASSESSMENT
(Moore and Garg, 1995)

LOCATION: Weld School DATE: 11/9/99
TASK: Simulated Honeycomb Weld Task

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Circle the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.					
Rating Criterion	***% MS*** **(percentage of maximal strength)**	***Borg Scale*** **(Compare to Borg Cr-10 Scale)**	***Perceived Effort***	***Rating*** **(circle)**	***Multiplier***
Light	**< 10%**	**< or = 2**	**barely noticeable or relaxed effort**	**1**	**1**
Somewhat Hard	**10 - 29%**	**3**	**noticeable or definite effort**	**2**	**3**
Hard	**30 - 49%**	**4 - 5**	**obvious effort; unchanged facial expression**	**3**	**6**
Very Hard	**50 - 79%**	**6 - 7**	**substantial effort; changes to facial expression**	**4**	**9**
Near Maximal	**> or = 80%**	**> 7**	**uses shoulder or trunk to generate force**	**5**	**13**
***Based on Borg results from weld study which were fairly light to moderate**		**Intensity of Exertion Multiplier (Fill in)**			3

Table 23 (continued). Honeycomb Welder Strain Index

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0

Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
% Duration of Exertion	**< 10**	**1**	**0.5**
= 100 x duration of all exertions (sec) / Total observation time (sec)	**10 - 29**	**2**	**1.0**
	30 - 49	**3**	**1.5**
= 100 x ________________ = 55	**50 -79**	**4**	**2.0**
	> or = 80	**5**	**3.0**
Based on arc time from MVTA which is @ 55%	**Duration of Exertion Multiplier (Fill in)**		**2**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0

Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
Efforts per Minute	**< 4**	**1**	**0.5**
= 100 x number of exertions / Total observation time (min)	**4 - 8**	**2**	**1.0**
	9 -14	**3**	**1.5**
= 100 x ______________ = 3	**15 -19**	**4**	**2.0**
Welding is very static, thus @ 3	**> or = 20**	**5**	**3.0**
	Efforts per Minute Multiplier (Fill in)		**3**

Table 23 (continued) Honeycomb Welder Strain Index

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Circle the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	***Wrist Extension*** **(Stetson et al, 1991)**	***Wrist Flexion*** **(Stetson et al, 1991)**	***Ulnar Deviation*** **(Stetson et al, 1991)**	***Perceived Posture***	***Rating*** **(circle)**	***Multiplier***
Very Good	**0 -10 degrees**	**0 - 5 degrees**	**0 - 10 degrees**	**perfectly neutral**	**1**	**1.0**
Good	**11 - 25 degrees**	**6 - 15 degrees**	**11 -15 degrees**	**near neutral**	**2**	**1.0**
Fair	**26 -40 degrees (37% of time)**	**16 - 30 degrees (1% of time)**	**16 - 20 degrees (51% of time)**	**non-neutral**	**3**	**1.5**
Bad	**41 - 55 degrees**	**31 - 50 degrees**	**21 -25 degrees**	**marked deviation**	**4**	**2.0**
Very Bad	**> 60 degrees**	**> 50 degrees**	**> 25 degrees**	**near extreme**	**5**	**3.0**
Can vary, hard to observe in live, but from mock up tapes...			**Hand/ Wrist Posture Multiplier (Fill in)**			**1.5**

Table 23 (continued) Honeycomb Welder Strain Index

5. **Speed of Work: An estimate of how fast the worker is working. Circle the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.**				
Rating Criterion	***Compared to MTM*** **-1 (observed pace is divided by MTM's predicted pace and expressed as %; See Barnes 1980)**	***Perceived Speed***	***Rating*** **(circle)**	***Multiplier***
Very Slow	**< or = 80%**	**extremely relaxed pace**	**1**	**1.0**
Slow	**81 - 90%**	**"taking one's own time"**	**2**	**1.0**
Fair	**91 -100%**	**"normal" speed of motion**	**3**	**1.0**
Fast	**101-115%**	**rushed, but able to keep up**	**4**	**1.5**
Very Fast	**> 115%**	**rushed and barely or unable to keep up**	**5**	**2.0**
			Speed of Work Multiplier (Fill in)	**1.0**

6. Duration of Task per Day: Either measured or obtained from plant personnel. Circle the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	***Rating Criterion***	***Rating*** **(circle)**	***Multiplier***
Duration of Task per Day (hrs)	**< or = 1 hrs**	**1**	**0.25**
= duration of task (hrs) + duration of task (hrs) + ...	**1 - 2 hrs**	**2**	**0.50**
= ____ + ____ + ____ + ____ =	**2 - 4 hrs**	**3**	**0.75**
@10-11 honeycombs per day, each take @22 minutes = 4.03 hrs	**4 - 8 hrs**	**4**	**1.00**
	> or = 8 hrs	**5**	**1.50**
	Duration of Task per Day Multiplier (Fill in)		**1.00**

Table 23 (continued) Honeycomb Welder Strain Index

Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**		**SI SCORE**
3 x	**2 x**	**3 x**	**1.5 x**	**1.0 x**	**1.0**	**=**	**27**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:

– SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
– SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
– SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
– SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 24. Honeycomb Welder UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
(Lifshitz and Armstrong, 1986)

Date/ Time 11/9/99 Area/ Shop Shipyard
Task: Honeycomb Welder
* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	No	Yes
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges?		**Y**
1.2 Is the tool operating without vibration?		**Y**
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?		**Y**
1.4 Can the job be done without using gloves?	**N**	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	**N**	
2.2 Can the job be done without using finger pinch grip?		**Y**
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	**N**	
3.2 Can the tool be used without flexion or extension of the wrist?	**N**	
3.3 Can the job be done without deviating the wrist from side to side?		**Y**
3.4 Can the tool be used without deviating the wrist from side to side?		**Y**
3.5 Can the worker be seated while performing the job?	**N**	
3.6 Can the job be done without "clothes wringing" motion?		**Y**
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	**N**	
4.2 Can the height of the work surface be adjusted?	**N**	
4.3 Can the location of the tool be adjusted?	**N**	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?		**Y**
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?		**Y**
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	**N**	
6.3 Is the handle of the tool made from material other than metal?		**Y**
6.4 Is the weight of the tool below 4 kg (9lbs)?		**Y**
6.5 Is the tool suspended?	**N**	
TOTAL	**10 (48%)**	**11 (52%)**

Table 25. Honeycomb Welder OWAS

OWAS: OVAKO Work Analysis System
(Louhevaara and Suurnäkki, 1992)
Procedure: Observe workers at intervals of 30-60 seconds and record the postures and forces over a representative period (~ 45 minutes)

Date/ Time 11/9/99 Area/ Shop: Shipyard
Task: Honeycomb Welder

Risk Factor	**Work Phase1: Arctime**	**Work Phase 2: De-Slagging**	**Work Phase 3 Change Sticks**	**Work Phase 4 Get New Sticks**	**Work Phase 5 Move to new Honey-comb**				
TOTAL Combination Posture Score	***4 or 2***	***4 or 2***	***4 or 2***	***1***	***1***				
Common Posture Combinations (collapsed across work phases)									
Back	4	1	2						
Arms	1	1	1						
Legs	6	7	6						
Posture Repetition (% of working time)	69	10	69*						
BACK % of Working Time SCORE	***3***	***1***	***2***						
ARMS % of Working Time SCORE	***1***	***1***	***1***						
LEGS % of Working Time SCORE	***3***	***1***	***3***						
ACTION CATEGORIES: *1 = no corrective measures* *2 = corrective measures in the near future* *3 = corrective measures as soon as possible* *4 = corrective measures immediately*									
Risk Factor	**Work Phase1: Arctime**	**Work Phase 2: De- Slagging**	**Work Phase 3 : Change Sticks**	**Work Phase 4 :Get New Sticks**	**Work Phase 5 : Move to new Honey-comb**				

Posture									
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2, 4	2,4	2,4	1	1				
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1	1				
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	6	6	6	7	7				
Load/ Use of Force									
1 = weight or force needed is = or <10 kg (<22lbs)	1	1	1	1	1				
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)									
3 = weight or force > 20 kg (>44 lbs)									
Phase Repetition									
% of working time (0,10,20,30,40,50,60,70,80,90,100)	56	12	> 1	6	4				

Table 25 (continued). Honeycomb Welder OWAS

Table 26. Honeycomb Welder PLIBEL

PLIBEL Checklist
(Kemmlert, 1995)

Date/ Time: 11/9/99 Area/ Shop: Shipyard
Task: Honeycomb Welder

Section I: Musculoskeletal Risk Factors

Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions (Preferred Method)
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	***Body Regions***				
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
1: Is the walking surface uneven, sloping, slippery or nonresilient?			**Y**	**Y**	**Y**
2: Is the space too limited for work movements or work materials?	**Y**	**Y**	**Y**	**Y**	**Y**
3: Are tools and equipment unsuitably designed for the worker or the task?	**Y**	**Y**	**Y**	**Y**	**Y**
4: Is the working height incorrectly adjusted?	**N**				**N**
5: Is the working chair poorly designed or incorrectly adjusted?	**N**				**N**
6: If work performed standing, is there no possibility to sit and rest?			**N**	**N**	**N**
7: Is fatiguing foot pedal work performed?			**N**	**N**	
8: Is fatiguing leg work performed? E.g. ...					
a) repeated stepping up on stool, step etc..?			**Y**	**Y**	**Y**
b) repeated jumps, prolonged squatting or kneeling?			**Y**	**Y**	**Y**
c) one leg being used more often in supporting the body?			**N**	**N**	**N**
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	**Y**				**Y**
b) severely flexed forward?	**Y**				**Y**
c) bent sideways or mildly twisted?	**Y**				**Y**
d) severely twisted?	**Y**				**Y**

Table 26 (continued). Honeycomb Welder PLIBEL

10: Is repeated or sustained work performed when the neck is:					
a) flexed forward?	**Y**				
b) bent sideways or mildly twisted?	**Y**				
c) severely twisted?	**N**				
d) extended backwards?	**Y**				
11: Are loads lifted manually? Notice factors of importance as:					
a) periods of repetitive lifting	**N**				**N**
b) weight of load	**N**				**N**
c) awkward grasping of load	**Y**				**Y**
d) awkward location of load at onset or end of lifting	**N**				**N**
e) handling beyond forearm length	**N**				**N**
f) handling below knee length	**N**				**N**
g) handling above shoulder height	**N**				**N**
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	**Y**	**Y**			**Y**
13: Is sustained work performed when one arm reaches forward or to the side without support?	**Y**				
14: Is there a repetition of:					
a) similar work movements?	**Y**	**Y**			
b) similar work movements beyond comfortable reaching distance?	**Y**	**Y**			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	**Y**	**Y**			
b) awkward grasping of working materials or tools	**Y**	**Y**			
16: Are there high demands on visual capacity?	**Y**				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		**Y**			
b) forceful movements?		**N**			
c) uncomfortable hand positions?		**Y**			
d) switches or keyboards?		**N**			

Table 26 (continued). Honeycomb Welder PLIBEL

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
SUM	**17**	**9**	**5**	**5**	**11**
PERCENTAGE	**65.4**	**81.8**	**62.5**	**62.5**	**52.4**

Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores	
18: Is there no possibility to take breaks and pauses?	**N**
19: Is there no possibility to choose order and type of work tasks or pace of work?	**Y**
20: Is the job performed under time demands or psychological stress	**Y**
21:Can the work have unusual or expected situations?	**Y**
22: Are the following present?	
a) cold	**Y**
b) heat	**Y**
c) draft	**Y**
d) noise	**Y**
e) troublesome visual conditions	**Y**
f) jerks, shakes, or vibration	**N**
Environmental / Organizational Risk Factors Score	
SUM	**8**
PERCENTAGE	**80.0**

APPENDIX C

PRE-INTERVENTION QUALITATIVE ERGONOMIC

HAZARD ANALYSIS

WORK TASKS ANALYZED:

Bin emptying at a dry-dock sorting pad

Onboard insulation removal

Use of reciprocating saws to separate and reduce the size of components and hull sections

The removal of terrazzo tile from the decking with a chipping hammer.

Manual materials handling in "Cut and Carry" operations

C1. Bin Emptying on Dry-dock Sorting Pad

Figure 3 Emptying Scrap Bin at Dry-dock Sorting Pad

C1.1 Bin Emptying at Dry-dock Sorting Pad Process

As the surface vessels and submarines are being dismantled as part of the Inactivation, Reactor Compartment Disposal, and Recycling activity, hundreds of bins of scrap metal are generated. Each bin measures approximately 5 feet by 3 feet by 3 feet. The bins hold a variety of material: stainless steel, painted steel, unpainted steel, aluminum, and other metal components. Each bin is filled during the "cut and carry" dismantling process for the vessel or vessels within the dry-dock. At the time of the site visit, four submarines were being dismantled within the same dry-dock. The scrap bins are moved from the vessels to the sorting pad area by forklifts. The sorting pad is surrounded by large shipping containers (approximately 5 feet x 20 feet), each for a specific type of metal.

The sorting pad worker removes the individual pieces of metal from the scrap bin by hand. The worker makes a determination of the type of metal in hand and then carries the item to the appropriate shipping container. The worker then places or throws the item into the shipping container and returns to the scrap bin for the next item. Each bin takes approximately 20 minutes to empty and sort. Individual items can weigh anywhere from a few ounces for metal strapping to in excess of fifty pounds for triple valve assemblies.

Figure 4. Worker Reaching to Bottom of Scrap Bin to Retrieve Item

Figure 5. Worker Hanging Over Edge of Scrap Bin and On One Leg

Figure 6. Working Lifting Triple Valve Assembly from Sorting Bin

Figure 7. Worker Carrying Triple Valve Assembly to Shipping Container

C1.2 Ergonomic Risk Factors for Sorting Pad Worker

The Sorting pad worker often must reach far in front or deep into the bin while grasping objects of unknown weight. Awkward postures of the back and neck, such as extreme lumbar flexion and neck extension, are fairly common. Strain of the shoulder, neck, and back is possible due to the manual lifting tasks. Some items are relatively heavy resulting in increased physiological strain on the worker.

C1.3 Ergonomic Analysis of Bin Emptying Task on Dry-dock Sorting Pad

Using several of the exposure assessment tools outlined previously, an ergonomic analysis was performed for the sorting pad worker emptying scrap bins. A Strain Index analysis was performed for the sorting pad worker (C9.1, Table 1) with the following results:

1) The Intensity of Exertion was rated as "Hard" and given a multiplier score of 6 on a scale of 1 to 13
2) The Duration of the task was rated as equal to or greater than 80 % of the task cycle, resulting in a multiplier of 3.0 on a scale of 0.5 to 3.0
3) The Efforts per Minute were noted to be between 15 and 19, resulting in a multiplier of 2.0 on a scale of 0.5 to 3.0
4) The Hand/Wrist posture was rated as "Fair," resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0
5) The Speed of Work was rated as "Normal," resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
6) The Duration of Task per Day was rated to be between 2 and 4 hours, resulting in a multiplier of 0.75 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 40.5. An SI Score of between 31 and 60 is correlated to an incidence rate of about 106 distal upper extremity injuries per 100 FTE. Regardless of actual incidence rate, the Strain Index indicates that this task puts the sorting pad worker at an increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the sorting pad worker bin emptying task (C9.1, Table 2), of the 21 possible responses, nine were negative and seven were positive (one question answered both positively and negatively, six questions were not applicable. Negative responses, in this case 56 %, are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the sorting pad worker (C9.1, Table 3), the need for corrective measures was suggested for a number of specific sub-tasks including: lifting items from the scrap bin, carrying items to the shipping containers, and scraping labels off the scrap bins.

The NIOSH checklist for manual materials handling consists of 14 items. When applied to the sorting pad worker bin emptying task (C9.1, Table 4), six responses were positive and eight negative. In this checklist, positive responses are indicative of conditions that pose a risk to the worker of developing low back pain. The higher the percentage of positive response, the greater the risk of low back pain.

The University of Michigan 3D Static Strength Prediction Program was used to analyze the sorting pad worker lifting a triple valve assembly from the bottom of a scrap bin (C9.1, Table 5). Analysis of this sub-task resulted in an estimated disc compression loads at the L5/S1 disc to be 972 pounds, well above the NIOSH Recommended Compression Limit of 770 pounds.

The PLIBEL checklist for the sorting pad worker task (C9.1, Table 6) reports a high percentage (~ 75 %) of risk factors present for the neck, shoulders, upper back, and lower back, and a moderate percentage (~ 60 %) of risk factors present for the elbows, forearms, and hands. Several environmental and organizational modifying factors are present as well.

C2. Insulation Removal on Surface Ship in Dry-dock

Figure 8 Worker Removing Insulation Tie Cap with Short Pry Bar

C2.1 Insulation Removal Process Insulators remove insulation from the bulkheads and ceilings of vessels being dismantled. The workers first cordon off the immediate work area to discourage entry by unauthorized personnel. This action is done by hanging warning tape and placards (e.g., “WARNING Man-Made Vitreous Fibers”) around the work area. The insulators don totally encapsulating chemical protective suits and supplied-air hoods under positive pressure. The initial task of the worker is to remove the insulation tie caps. These small, round disks secure the insulation onto the metal insulation studs. These disks are removed using pry bars or wrecking bars of various sizes while standing on ladders to reach the overhead insulation.

Figure 9. Insulator Removing Insulation Tie Cap Overhead

Figure 10. Insulator Removing Insulation Tie Cap with Short Bar

Once all the insulation tie caps have been removed, the worker uses a hawksbill knife (i.e., a knife with a short, downward-curved blade) to cut the insulation into manageable widths of approximately 18 inches. While cutting into the insulation, a co-worker sprays the surrounding air with a water mist to entrap any loose fibers that may otherwise be respirable.

Figure 11. Insulation Worker Cutting into Insulation with Hawksbill Knife

The worker then pulls on the insulation to break it free from the bulkhead or overhead area. The insulation is bagged and disposed of properly.

Figure 12. Pulling off insulation in overhead area by hand

Figure 13. Pulling Section of Insulation Off Bulkhead by Hand

C2.2 Ergonomic Risk Factors for Insulation Removal Workers

The vast majority of work for the insulation removal workers is performed with arms overhead or out in front and away from the body, either using pry bars or knives, straining the arms, shoulders, and neck. Often the worker is on a ladder and is leaning backward (back extension) to get to the work as opposed to repositioning the ladder. Back extension such as this can be stressful to the worker. Pulling the insulation off the bulkheads or overhead areas requires the use of force to separate the insulation from the surface areas. This task is stressful to the arms, shoulders, neck and back. All of these tasks are performed while the worker is wearing an encapsulating chemical-protective suit with a supplied air respirator causing an increased physiological strain on the worker.

C2.3 Ergonomic Analysis of Insulation Removal Workers

Using several of the exposure assessment tools outlined previously, an ergonomic analysis was conducted for the tasks of the insulation removal worker. A Rapid Upper Limb Assessment analysis was conducted for the insulation removal workers (C9.2, Table 7). Five separate tasks were analyzed: 1) using a small pry bar to remove insulation tie caps, 2) using a hawksbill knife to cut the insulation, 3) using a crowbar to pry insulation off the bulkhead, 4) using two hands to pull insulation down, and 5) moving the ladder to the next location. Tasks # 1, 2, and 3 resulted in a response to "investigate and change immediately." Task # 4 resulted in a response to "investigate and change soon." Task # 5 resulted in a response to "investigate further."

A Strain Index analysis was performed for the insulation removal worker (C9.2, Table 8) with the following results:

1) The Intensity of Exertion was rated as "Very Hard" and given a multiplier score of 9 on a scale of 1 to 13
2) The Duration of the task was rated as equal to or greater than 80 % of the task cycle, resulting in a multiplier of 3.0 on a scale of 0.5 to 3.0
3) The Efforts per Minute were noted to be greater than 20 per minute, resulting in a multiplier of 3.0 on a scale of 0.5 to 3.0
4) The Hand/Wrist posture was rated as "Bad," resulting in a multiplier of 2.0 on a scale of 1.0 to 3.0
5) the Speed of Work was rated as "Normal," resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0

6) the Duration of Task per Day was rated to be between 2 and 4 hours, resulting in a multiplier of 0.75 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For the insulation removal tasks the SI score was 121.5. An SI Score greater than 60 is correlated to an incidence rate of about 130 distal upper extremity injuries per 100 FTE. Regardless of actual incidence rate, the Strain Index indicates that this task puts the insulation removal worker at an increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the insulation removal worker tasks (C9.2, Table 9), of the 21 possible responses, eighteen were negative and four were positive (one question answered both positively and negatively). Negative responses, in this case 82 %, are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the insulation removal tasks (C9.2, Table 10), the need for corrective measures “as soon as possible” was suggested for the task of removing the insulation tie caps with a small pry bar. Four other tasks called for corrective measures “in the near future” including: moving the ladder, cutting the insulation with a hawksbill knife, loosening the insulation with a small pry bar, and pulling the insulation off the bulkheads and overhead areas by hand.

The PLIBEL checklist for the insulation removal tasks (C9.2, Table 11) reports a very high percentage (~ 91 %) of risk factors present for the elbows, forearms and hands. A moderate percentage (~ 45-62 %) of risk factors were reported present for the neck, shoulders, upper back and lower back. Several environmental and organizational modifying factors are present as well.

C3. Reciprocating Saw Operations in the IRR Process

Figure 15. Two-Person Cutting Operation for Ductwork with Possible Hazardous Material

C3.1 Cutting Process with Reciprocating Saws

Ship dismantling, or Inactivation, Reactor Compartment Disposal, and Recycling as the process is known, requires the separation of components, bulkheads, and hull sections from adjoining locations. This separation is accomplished either by torch cutting or by using a reciprocating saw to cut through the steel, aluminum or other material. Torch cutting requires a fire-watch crew to stand by and a certain level of expertise by the user. Cutting with a reciprocating saw does not require the fire-watch crew and can be accomplished by nearly every worker making it the preferred method among supervisors. Also, areas containing suspected hazardous materials must be mechanically cut to minimize worker exposure to the substance. Chemical protective clothing is worn when there is the possibility of exposure to known hazards. Mechanical cutting can take place overhead to remove wire hangers, between shoulder and floor height to remove bulkheads, or below floor level to remove decking and supports. Some components are lowered to the deck to be cut to reduce the amount of overhead work.

Figure 16. Worker Using Reciprocating Saw While Kneeling

Figure 17. Kneeling Worker Changing Blade on Reciprocating Saw

Workers assume a variety of postures to cut the pieces of metal including kneeling, sitting, lying down, bending over, standing on ladders, etc. Workers typically cut for 2-3 hours and then carry cut material to a disposal area for another 2 hours. Workers often work in pairs, switching between cutting the material with the eight pound reciprocating saw and supporting the item being cut. Heavier items are removed using tandem lifts.

Figure 18. Kneeling Workers Planning Next Cut Sequence

Figure 19. Kneeling Workers Adjusting Position of Ductwork Being Cut

C3.2 Ergonomic Risk Factors for Reciprocating Saw Operators

The ergonomic risk factors for reciprocating saw operators include: awkward postures of the spine and wrist, static kneeling postures, forceful exertion of the upper extremity to hold the reciprocating saw, and high noise exposure. Particularly significant is the exposure to hand-arm or segmental vibration from using the powered reciprocating saw. (Vibration damping gloves are required personal protective equipment while using the saw). Normal operation of the saw results in vibration that has been reduced by an anti-vibration mechanism incorporated into the design of the saw. However, when initiating a cut (plunge cutting) or when the blade binds in the material, an extreme amount of vibration is transferred to the arm of the user. The manual material handling of the cut pieces may result in back, neck or shoulder strain of the workers.

C3.3 Ergonomic Analysis of Reciprocating Saw Operator Tasks

A Rapid Upper Limb Assessment analysis was conducted for the reciprocating saws operator tasks (C9.3, Table 12). Five separate tasks were analyzed: 1) sawing while kneeling, 2) sawing while standing, 3) changing saw blade while kneeling, 4) kneeling and planning next cut with co-worker, and 5) manually lifting piece to reposition item. Tasks # 1, 2, 3, and 5 resulted in a response to "investigate and change immediately." Task # 4 resulted in a response to "investigate further."

A Strain Index analysis was performed for the reciprocating saw worker (C9.3, Table 13) with the following results:

1) the Intensity of Exertion was rated as "Hard" and given a multiplier score of 6 on a scale of 1 to 13
2) the Duration of the task was rated as equal to or greater than 80 % of the task cycle, resulting in a multiplier of 3.0 on a scale of 0.5 to 3.0
3) the Efforts per Minute were noted to be greater than 20 per minute, resulting in a multiplier of 3.0 on a scale of 0.5 to 3.0
4) the Hand/Wrist posture was rated as "Bad," resulting in a multiplier of 2.0 on a scale of 1.0 to 3.0
5) the Speed of Work was rated as "Normal," resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
6) the Duration of Task per Day was rated to be between 2 and 4 hours, resulting in a

multiplier of 0.75 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For the reciprocating saw worker tasks the SI score was 81. An SI Score greater than 60 is correlated to an incidence rate of about 130 distal upper extremity injuries per 100 FTE. Regardless of actual incidence rate, the Strain Index indicates that this task puts the reciprocating saw worker at an increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the reciprocating saw worker tasks (C9.3, Table 14), of the 21 possible responses, sixteen were negative and six were positive (one question answered both positively and negatively). Negative responses, in this case 73 %, are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the reciprocating saw worker tasks (C9.3, Table 15), the need for “corrective measures in the near future” was suggested for six of the eight tasks analyzed. These tasks were: sawing while kneeling, sawing while standing, changing the blade while kneeling and repositioning the saw, body, or workpiece.

The NIOSH checklist for manual materials handling consists of 14 items. When applied to the reciprocating saw worker tasks (C9.3, Table 16), six responses were positive and eight negative. In this checklist, positive responses (43 %) are indicative of conditions that pose a risk to the worker of developing low back pain. The higher the percentage of positive response, the greater the risk of low back pain.

The PLIBEL checklist for the reciprocating saw worker tasks (C9.3, Table 17) reports a very high percentage (~ 82 %) of risk factors present for the elbows, forearms and hands. A moderate percentage (~ 57-65 %) of risk factors were reported present for the neck, shoulders, upper back and lower back. Several environmental and organizational modifying factors are present as well.

C4. Tile Chipping Operations

Figure 20. Worker Using Chipping Hammer to Remove Terrazzo Tile from Deck Surface

C4.1 Removal of Terrazzo Tile with Chipping Hammer

During the outfitting of vessels, some of the decking surfaces are covered in tile. This is particularly true of mess hall and lavatory facilities. Before the deck plate can be cut be either torch or reciprocating saw, a path must be cleared of tile. The tile is removed by using a chipping hammer to break the tile and flake the tile off the deck surface. This task requires the worker to kneel, sit or bend over the deck surface to operate the chipping hammer.

Figure 21. Working Using Chipping Hammer Nearly Parallel to Tile

Figure 22. Worker Brushing Away Chipped Tile Shards

C4.2 Ergonomic Risk Factors for Tile Chipping Worker

Chipping tile from deck surfaces puts the worker in awkward postures, having to kneel or sit on the deck. The back and neck are flexed. Exposure to hand-arm or segmental vibration is bad, having to hold the chipping blade in place with one hand while holding the tool weight and operating the trigger with the other hand. Few improvements to these tools have been made since the turn of the century. Noise exposure is also very high with the use of chipping hammers.

C4.3 Ergonomic Analysis of Tile Chipping Tasks

A Rapid Upper Limb Assessment analysis was conducted for the tile chipping tasks (C9.4, Table 18). Five separate tasks were analyzed: 1) chipping perpendicular to tile, 2) chipping parallel to tile, 3) re-positioning the chipping hammer, 4) brushing aside broken tile shards, and 5) re-positioning the worker Tasks # 1, 2, and 3 resulted in a response to "investigate and change immediately." Tasks # 4 and 5 resulted in a response to "investigate further."

A Strain Index analysis was performed for the tile chipping saw worker (C9.4, Table 19) with the following results:

1) the Intensity of Exertion was rated as "Hard" and given a multiplier score of 6 on a scale of 1 to 13

2) the Duration of the task was rated as equal to or greater than 80 % of the task cycle,

resulting in a multiplier of 3.0 on a scale of 0.5 to 3.0

3) the Efforts per Minute were noted to be about 12.5 times per minute, but were also quite static. A compromise rating was given, resulting in a multiplier of 2.0 on a scale of 0.5 to 3.0

4) the Hand/Wrist posture was rated as "Bad," resulting in a multiplier of 2.0 on a scale of 1.0 to 3.0

5) the Speed of Work was rated as "Normal," resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0

6) the Duration of Task per Day was rated to be between 2 and 4 hours, resulting in a multiplier of 0.75 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For the tile chipping tasks the SI score was 54. An SI Score between 30 and 60 is correlated to an incidence rate of about 106 distal upper extremity injuries per 100 FTE. Regardless of actual incidence rate, the Strain Index indicates that this task puts the tile chipping worker at an increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the tile chipping tasks (C9.4, Table 20), of the 21 possible responses, seventeen were negative and five were positive (one question answered both positively and negatively). Negative responses, in this case 77 %, are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the tile chipping tasks (C9.4, Table 21), the need for "corrective measures in the near future" was suggested for five of the six tasks analyzed. These tasks were: chipping perpendicular to tile, chipping parallel to tile, brushing away loose tile, and repositioning the chipping hammer or the body.

The NIOSH checklist for manual materials handling consists of 14 items. When applied to the tile chipping tasks (C9.4, Table 22), six responses were positive and eight negative. In this checklist, positive responses (43 %) are indicative of conditions that pose a risk to the worker of developing low back pain. The higher the percentage of positive response, the greater the risk of low back pain.

The PLIBEL checklist for the tile chipping tasks (C9.4, Table 23) reports a very high percentage (~ 82 %) of risk factors present for the elbows, forearms and hands. A moderate percentage (~ 47-65 %) of risk factors were reported present for the neck, shoulders, upper back and lower back. Several environmental and organizational modifying factors are present as well.

C5. Manual Material Handling in the “Cut and Carry” Process within IRR

Figure 23 Workers Performing Tandem Lift of Scrap Material Inside Vessel

Figure 24. Worker Pulling Scrap Loose from Pile

C5.1 Manual Material Handling in Ship Dismantling Tasks

As part of the Inactivation, Reactor Compartment Disposal, and Recycling process, material is cut apart and stored at temporary locations within the vessel being dismantled. This material is then manually moved from the internal storage areas to scrap bins for removal from the ship by crane. Depending on how the material was cut, it may require more than one individual to safely lift the object and carry it to the scrap bin. Somewhat confined spaces and the clutter of the stored material create tripping hazards in the narrow passageways.

Figure 25. Moving Scrap Material from Storage Pile

Figure 26. Workers Placing Scrap in Bin for Transport Off Ship

C5.2 Ergonomic Risk Factors for Manual Material Handling Workers

The manual material handling of scrap metal may result in strains of the lower back, neck, shoulder and upper extremities. Tripping hazards may be present. Sharp edges on the cut metal may cause lacerations to ungloved hands.

C5.3 Ergonomic Analysis of Carrying Tasks in Ship Dismantling

A Strain Index analysis was performed for the manual material handling tasks in the "cut and carry" operation (C9.5, Table 24) with the following results:

1) the Intensity of Exertion was rated as "Somewhat Hard" and given a multiplier score of 3 on a scale of 1 to 13

2) the Duration of the task was rated as being between 30 and 49 percent of the task cycle, resulting in a multiplier of 1.5 on a scale of 0.5 to 3.0

3) the Efforts per Minute were noted to be less than 4 per minute, resulting in a multiplier of 0.5 on a scale of 0.5 to 3.0

4) the Hand/Wrist posture was rated as “Fair,” resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0

5) the Speed of Work was rated as “Normal,” resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0

6) the Duration of Task per Day was rated to be between 2 and 4 hours, resulting in a multiplier of 0.75 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For the manual material handling tasks, the SI score was 2.5. An SI Score less than 5 is correlated to an incidence rate of about 2 distal upper extremity injuries per 100 FTE.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the reciprocating saw worker tasks (C9.5, Table 25), of the 21 possible responses, nine were negative and six were positive, and 6 were not applicable (one question answered both positively and negatively). Negative responses, in this case 60 %, are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the manual material handling tasks (C9.5, Table 26), the need for “corrective measures in the near future” was suggested for only two of the seven tasks analyzed. These tasks were arranging items in the scrap bin and lifting materials.

The NIOSH checklist for manual materials handling consists of 14 items. When applied to the reciprocating saw worker tasks (C9.5, Table 27), five responses were positive and nine negative. In this checklist, positive responses (36 %) are indicative of conditions that pose a risk to the worker of developing low back pain. The higher the percentage of positive response, the greater the risk of low back pain.

The University of Michigan 3D Static Strength Prediction Program was used to analyze a variety of manual material handling tasks performed in the “cut and carry” operation (C9.5, Table 28). Analysis of these sub-task resulted in estimated disc compression loads at the L5/S1 disc ranging from 311.8 pounds for a tandem lift of 40 pounds to 741.4 pounds for lifting a 40 pound item within the scrap bin. All results were below the NIOSH Recommended Compression Limit of 770 pounds.

The PLIBEL checklist for the manual material handling tasks in the “cut and carry” operation (C9.5, Table 29) reports a moderate percentage (~ 50-67 %) of risk factors were reported present for the neck, shoulders, upper extremities, lower extremities, upper back and lower back. Several environmental and organizational modifying factors are present as well.

C6. CONTROL TECHNOLOGY

Possible interventions and control technologies are mentioned briefly here. A more detailed report of possible interventions is in preparation.

C6.1 Bin Emptying by Sorting Pad Worker Possible Interventions

Changes in how the scrap bins are presented to the worker may help in eliminating the extreme back flexion required to reach to the bottom of the bins to remove items. Tilting pallet jacks can be used to tilt the scrap bin once some of the material has been distributed to the shipping containers. The scrap material can be dumped from the bins onto an elevated rotating turntable. This elevated turntable would minimize the need of the worker to bend into the bins to remove materials. Short hooked poles can be provided to move material from the center of the table to the edge to allow the worker to grasp it. Ultimately, the accurate sorting of material into separate scrap bins at the vessel would eliminate the need for the sorting pad.

C6.2. Insulation Removal Possible Interventions

A high percentage of the insulation removal tasks require the worker to stand on ladders and work overhead. Elevated work platforms would provide a more stable standing surface than ladders. The platforms may be elevated close to the ceiling to allow the worker to lay down and work with arms in front of the body as opposed to working above shoulder height. Removal of the insulation tie caps with a pry bar can be replaced with mechanical cutters.

C6.3 Reciprocating Saw Operators Possible Interventions

The use of reciprocating saws can be minimized by the increase in use of torch cutting. Time savings in length of time require to complete the cut in part offsets the requirement for a fire-watch crew. If saws are utilized, the use of wheeled tripods or standing jigs as developed at the shipyard will remove the worker from the vibration exposure. The addition of a stabilizing handle near the front of the tool that isolates some of the vibration from the worker is also a good idea. Modifying the saw trigger mechanism to work from palm pressure as opposed to finger pressure was also done at this shipyard to minimize trigger finger complaints.

C6.4 Tile Chipping Possible Interventions

Removing tile from deck surfaces requires the worker to kneel or sit on the deck. Providing kneel pads or cushions minimizes some of the contact stresses. If chipping hammers can not be replaced as the tool of choice, it is recommended that the widest blade possible be used on the hammer to minimize exposure time

C6.5 Manual Material Handling in "Cut and Carry" Operation Possible Interventions

Ship dismantling requires that all internal components are remove from the vessel before it is cut to pieces. The removal of components through ship passageways to staging areas is currently performed by manual material handling. There is the possibility that flexible conveyor systems can be used to either move material to the staging area or to move material into the scrap bins in the staging areas. Portable hoists may be useful in the staging areas as well to move heavy or bulky material.

C7. CONCLUSIONS AND RECOMMENDATIONS

Five distinct work processes within a ship dismantling operation were surveyed to determine the presence of risk factors associated with musculoskeletal disorders. Each work process was analyzed using a number of exposure assessment techniques. Possible interventions highlighted here for the five work tasks analyzed will be discussed in much greater detail in a forthcoming report by the Project Group.

It is recommended that further action be taken to mitigate the exposure to musculoskeletal risk factors within each of the identified tasks. The implementation of ergonomic interventions has been found to reduce the amount and severity of musculoskeletal disorders within the working population in various industries.

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C9. Tables

C9.1 Sorting Pad Worker

Table 1. Sorting Pad Worker Strain Index

STRAIN INDEX: DISTAL UPPER EXTREMITY (DUE) DISORDERS RISK ASSESSMENT
(Moore and Garg, 1995)

LOCATION:
TASK: Bin emptying by sorting pad worker

1. **Intensity of Exertion:** An estimate of the strength required to perform the task one time. Circle the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	***% MS*** (percentage of maximal strength)	***Borg Scale*** (Compare to Borg Cr-10 Scale)	***Perceived Effort***	***Rating*** (circle)	***Multiplier***
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3
Hard	**30 - 49%**	**4 - 5**	**obvious effort; unchanged facial expression (*28 -38% of observed time > = Hard)**	**3**	**6**
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13
				Intensity of Exertion Multiplier	**6**

Table 1 (continued). Sorting Pad Worker Strain Index

2. **Duration of Exertion (% of cycle)**: Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.***NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0**

Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
% Duration of Exertion	< 10	1	0.5
= 100 x duration of all exertions (sec) / Total observation time (sec)	10 - 29	2	1.0
	30 - 49	3	1.5
= 100 x 993 (sec)/ 1168 (sec) = 85	50 -79	4	2.0
	> or = 80	**5**	**3.0**
		Duration of Exertion Multiplier	**3.0**

3. **Efforts per Minute:** Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. ***NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0**

Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
Efforts per Minute	< 4	1	0.5
= number of exertions / Total observation time (min)	4 - 8	2	1.0
	9 -14	3	1.5
= [total # of efforts for observed period, 298/ Total observed time (min) 19.46]	**15 -19**	**4**	**2.0**
= 15.31	> or = 20	5	3.0
		Efforts per Minute Multiplier	**2.0**

Table 1 (continued). Sorting Pad Worker Strain Index

4. **Hand/ Wrist Posture:** An estimate of the position of the hand or wrist relative to neutral position. Circle the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	***Wrist Extension*** (Stetson et al, 1991)	***Wrist Flexion*** (Stetson et al, 1991	***Ulnar Deviation*** (Stetson et al, 1991	***Perceived Posture***	***Rating*** (circle)	***Multiplier***
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	**26 -40 degrees**	**16 - 30 degrees**	**16 - 20 degrees**	**non-neutral**	**3**	**1.5**
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
					Hand/ Wrist Posture Multiplier	**1.5**

Table 1 (continued). Sorting Pad Worker Strain Index

5. **Speed of Work:** An estimate of how fast the worker is working. Circle the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	***Compared to MTM*** -1 (observed pace is divided by MTM's predicted pace and expressed as % ; See Barnes 1980)	***Perceived Speed***	***Rating*** (circle)	***Multiplier***
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	**91 -100%**	**"normal" speed of motion**	**3**	**1.0**
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed and barely or unable to keep up	5	2.0
			Speed of Work Multiplier	**1.0**

6. **Duration of Task per Day:** Either measured or obtained from plant personnel. Circle the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	***Rating Criterion***	***Rating*** (circle)	***Multiplier***
Duration of Task per Day (hrs)	< or = 1 hrs	1	0.25
= duration of task (hrs) + duration of task (hrs) + ...	1 - 2 hrs	2	0.50
	2 - 4 hrs	**3**	**0.75**
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
		Duration of Task per Day Multiplier	**0.75**

Table 1 (continued). Sorting Pad Worker Strain Index

Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**		**SI SCORE**
6 x	**3 x**	**2 x**	**1.5 x**	**1 x**	**.75**	**=**	**40.5**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:

– SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;

– SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;

– SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;

– SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 2. Sorting Pad Worker UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders (Lifshitz and Armstrong, 1986)

Date/ Time 10/21/99 Facility Area/ Shop: Dry-dock
Task Bin Sorting Performed by:
* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	No	Yes
1. **Physical Stress**		
1.1 Can the job be done without hand/ wrist contact with sharp edges	N	
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N*	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N/A	N/A
3.3 Can the job be done without deviating the wrist from side to side?		Y
3.4 Can the tool be used without deviating the wrist from side to side?		Y
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	

4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N/A	N/A
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	N/A	N/A
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	N/A	N/A
6.3 Is the handle of the tool made from material other than metal?	N/A	N/A
6.4 Is the weight of the tool below 4 kg (9lbs)?	N/A	N/A
6.5 Is the tool suspended?	N/A	N/A
TOTAL	9 (56%)	7 (44%)

Table 3. Sorting Pad Worker OWAS

OWAS: OVAKO Work Analysis System (Louhevaara and Suurnäkki, 1992)

Procedure: Observe workers at intervals of 30-60 seconds and record the postures and forces over a representative period (~ 45 minutes)

Date/ Time 10/21/99 Facility Area/ Shop: Dry-dock
Task: Scrap Bin Sorting Performed by:

	Work Phase1: Lifting piece from receiving bin	**Work Phase 2 Carrying piece to separator bin**	**Work Phase 3 Throwing piece into separate bin**	**Work Phase 4 Walking back to receiving bin**	**Work Phase 5 Sweeping out receiving bin**	**Work Phase 6 Scraping labels off receiving bin**	**Work Phase 7 Cutting off zip ties**
TOTAL Combination Posture Score	***3***	***3***	***1***	***1***	***1***	***4***	***1***
Common Posture Combinations (collapsed across work phases)							
Back	2	2	4	4	1	4	1
Arms	1	1	1	1	1	1	1
Legs	2	3	2	3	7	4	2
Posture Repetition (% of working time)	38*	38*	38*	38*	56	3	1
BACK % of Working Time SCORE	***2***	***2***	***3***	***3***	***1***	***1***	***1***
ARMS % of Working Time SCORE	***1***	***1***	***1***	***1***	***1***	***1***	***1***
LEGS % of Working Time SCORE	***1***	***2***	***1***	***2***	***1***	***1***	***1***

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Risk Factor	Work Phase1: Lifting piece from receiving bin	Work Phase 2 Carrying piece to separator bin	Work Phase 3 Throwing piece into separate bin	Work Phase 4 Walking back to receiving bin	Work Phase 5 Sweeping out receiving bin	Work Phase 6 Scraping labels off receiving bin	Work Phase 7 Cutting off zip ties
Posture							
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2, 4	1	1	1	1	4	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	2,3	7	7	7	7	4	2
Load/ Use of Force							
1 = weight or force needed is = or <10 kg 2 = weight or force > 10 but < 20kg 3 = weight or force > 20 kg	3	3	3	1	1	1	1
Phase Repetition							
% of working time (0,10,20,30,40,50,60,70,80,90,100)	38	13	13	14	16	03	01

Table 3 (continued). Sorting Pad Worker OWAS

Table 4. Sorting Pad Worker NIOSH Manual Materials Handling Checklist
NIOSH Hazard Evaluation Checklist for Lifting, Carrying, Pushing, or Pulling (Waters and Putz-Anderson, 1996)

Date/ Time 10/21/99 Facility Area/ Shop: Dry-dock Sorting Pad
Task: Scrap Bin Sorting Performed by: Steve Wurzelbacher

RISK FACTORS	YES	NO
General		
1.1 Does the load handled exceed 50 lbs?	Y (sometimes)	
1.2 Is the object difficult to bring close to the body because of it's size, bulk, or shape?	Y	
1.3 Is the load hard to handle because it lacks handles or cutouts for handles, or does it have slippery surfaces or sharp edges?	Y	
1.4 Is the footing unsafe? For example, are the floors slippery, inclined, or uneven?		N
1.5 Does the task require fast movement, such as throwing, swinging, or rapid walking?	Y	
1.6 Does the task require stressful body postures such as stooping to the floor, twisting, reaching overhead, or excessive lateral bending?	Y (extreme lumbar flexion)	
1.7 Is most of the load handled by only one hand, arm, or shoulder?		N
1.8 Does the task require working in environmental hazards, such as extreme temperatures, noise, vibration, lighting, or airborne contamination?		N (cold, heat occasionally)
1.9 Does the task require working in a confined area?		N
Specific		
2.1 Does the lifting frequency exceed 5 lifts per minute (LPM)?		N (LPM = 4.5 over total cycle time, but some multiple lifts are counted singly)
2.2 Does the vertical lifting distance exceed 3 feet?	Y (sometimes)	
2.3 Do carries last longer than 1 minute?		N
2.4 Do tasks which require large sustained pushing or pulling forces exceed 30 seconds duration?		N (usually @ 5-10)
2.5 Do extended reach static holding tasks exceed 1 minute?		N
TOTAL	6 (43%)	8 (57%)

* “YES” responses are indicative of conditions that pose a risk of developing low back pain; the larger the percentage of “YES” responses, the greater the risk.

Table 5. Sorting Pad Worker 3D Static Strength Prediction Program

3D Static Strength Prediction Program (University of Michigan, 1997)

Date/ Time: 10/21/99
Area/ Shop: Dry-dock Sorting Pad
Facility:
Task: Scrap Bin Sorting

Work Element: Scrap Bin Sorting	**Disc Compression (lbs) @ L5/S1** (Note: NIOSH Recommended Compression Limit (RCL) is 770 lbs)
Two-handed lift from the bottom of the scrap bin, supported on one leg. Item (triple valve assembly) weighs 70 lbs.	**972 lbs.** (beginning of lift)

Table 6. Sorting Pad Worker PLIBEL

PLIBEL Checklist (Kemmlert, 1995)

Date/ Time: 10/21/99 Facility: Area/ Shop: Plate Shop
Task: Scrap Bin Sorting Performed by: Steve Wurzelbacher

Section I: Musculoskeletal Risk Factors

Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions (Preferred Method)
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	*Body Regions*				
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
1: Is the walking surface uneven, sloping, slippery or nonresilient?			N	N	N
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			Y	Y	Y
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? E.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	Y				Y
d) severely twisted?	Y				Y

Table 6 (continued). Sorting Pad Worker PLIBEL

10: Is repeated or sustained work performed when the neck is:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	Y				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Notice factors of importance as:					
a) periods of repetitive lifting	Y				Y
b) weight of load	Y				Y
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	Y				Y
e) handling beyond forearm length	Y				Y
f) handling below knee length	Y				Y
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	N				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		Y			
c) uncomfortable hand positions?		N			
d) switches or keyboards?		N			

Table 6 (continued). Sorting Pad Worker PLIBEL

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
SUM	20	7	2	2	15
PERCENTAGE	76.9	63.6	25.0	25.0	71.4

Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores	
18: Is there no possibility to take breaks and pauses?	N
19: Is there no possibility to choose order and type of work tasks or pace of work	N
20: Is the job performed under time demands or psychological stress	N
21:Can the work have unusual or expected situations?	N
22: Are the following present?	
a) cold	Y
b) heat	Y
c) draft	Y
d) noise	Y
e) troublesome visual conditions	N
f) jerks, shakes, or vibration	N
Environmental / Organizational Risk Factors Score	
SUM	4
PERCENTAGE	40.0

C9.2 Insulators

Table 7. Insulators RULA

Rapid Upper Limb Assessment (RULA) (Matamney and Corlett, 1993)

Date/Time: 10/21/99 Facility: Area/ Shop: Surface Vessel in Dry-dock
Task : Removal of Insulation from Bulkhead Surfaces Performed by: Steve Wurzelbacher

RULA Component	Frame # 53939 Using small crow-bar to pop off insulating tie caps overhead (standing on ladder)		Frame # 67499 Using hawksbill knife to cut insulation (overhead)		Frame # 68850 Using small crowbar to pry off insulation		Frame # 72030 Pulling insulation off by hand		Frame # 59220 Moving ladder	
	Specific	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***
Shoulder Extension/ Flexion	hyp flex	4	hyp flex	4	hyp flex	4	hyp flex	4	sl flex	2
Shoulder is Raised (+1)		1		1		1		1		0
Upper Arm Abducted (+1)		1		1		1		1		1
Arm supported, leaning (-1)		0		0		0		0		0
Elbow Extension/ Flexion	ext	1	neut	2	ext	1	ext	1	neut	2
Shoulder Abduction/ Adduction	m abd	1	m abd	1	m abd	1	m abd	1	m abd	1
Shoulder Lateral/ Medial	lat	1	lat	1	neut	0	lat	1	lat	1
Wrist Extension/ Flexion	ext	2	flx	2	ext	2	flx	2	neut	1
Wrist Deviation	ulnar	1	rad	1	rad	1	ulnar	1	neut	0
Wrist Bent from Midline (+1)		0		0		0		0		0
Wrist Twist (1) In mid range **Or** (2) End of range		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		1		1		0
Arm and Wrist Force/ load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		3		3		3		3		1
Neck Extension/ Flexion		2		2		2		2		2

Neck Twist (+1)		1		1		0		0		0
Neck Side-Bent (+1)		1		1		0		0		0
Trunk Extension/ Flexion	ext	1	neut	1	ext	1	neut	1	sl flex	2
Trunk Twist (+1)		1		0		0		0		0
Trunk Side Bend (+1)		1		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		1		1		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		2		2		2		1
Total RULA Score	**7**		**7**		**7**		6		3	

1 or 2 = ACCEPTABLE
3 or 4 = INVESTIGATE FURTHER
5 or 6 = INVESTIGATE FURTHER AND CHANGE SOON
7 = INVESTIGATE AND CHANGE IMMEDIATELY

Table 7 (continued). Insulators RULA

Table 8. Insulators Strain Index

STRAIN INDEX: DISTAL UPPER EXTREMITY (DUE) DISORDERS RISK ASSESSMENT (Moore and Garg, 1995)

LOCATION: Surface Ship in Dry-dock, 10/21/99

TASK: Removal of Insulation from Bulkheads and Systems

1. **Intensity of Exertion:** An estimate of the strength required to perform the task one time. Circle the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.					
Rating Criterion	***% MS*** (percentage of maximal strength)	***Borg Scale*** (Compare to Borg Cr-10 Scale)	***Perceived Effort***	***Rating*** (circle)	***Multiplier***
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6
Very Hard	**50 - 79%**	**6 - 7**	**substantial effort; changes to facial expression (79% of observed time > = Hard, due to overhead work)**	**4**	**9**
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13
				Intensity of Exertion Multiplier	**9**

Table 8 (continued). Insulators Strain Index

2. **Duration of Exertion (% of cycle)**: Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.***NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0**

Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
% Duration of Exertion	< 10	1	0.5
= 100 x duration of all exertions (sec) / Total observation time (sec)	10 - 29	2	1.0
	30 - 49	3	1.5
= 100 x 2066 (sec)/ 2289 (sec) = 90	50 -79	4	2.0
	> or = 80	**5**	**3.0**
		Duration of Exertion Multiplier	**3.0**

3. **Efforts per Minute:** Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. ***NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0**

Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
Efforts per Minute	< 4	1	0.5
= number of exertions / Total observation time (min)	4 - 8	2	1.0
	9 -14	3	1.5
= nearly static exertion, therefore **multiplier = 3**	15 -19	4	2.0
	> or = 20	**5**	**3.0**
		Efforts per Minute Multiplier	**3.0**

Table 8 (continued). Insulators Strain Index

4. **Hand/ Wrist Posture:** An estimate of the position of the hand or wrist relative to neutral position. Circle the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	***Wrist Extension*** (Stetson et al, 1991)	***Wrist Flexion*** (Stetson et al, 1991	***Ulnar Deviation*** (Stetson et al, 1991	***Perceived Posture***	***Rating*** (circle)	***Multiplier***
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral	3	1.5
Bad	**41 - 55 degrees**	**31 - 50 degrees**	**21 -25 degrees**	**marked deviation (*estimated, based on RULA performed)**	**4**	**2.0**
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**2.0**

Table 8 (continued). Insulators Strain Index

5. **Speed of Work:** An estimate of how fast the worker is working. Circle the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	***Compared to MTM*** -1 (observed pace is divided by MTM's predicted pace and expressed as %; See Barnes 1980)	***Perceived Speed***	***Rating*** (circle)	***Multiplier***
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	**91 -100%**	**"normal" speed of motion**	**3**	**1.0**
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed and barely or unable to keep up	5	2.0
			Speed of Work Multiplier	**1.0**

6. **Duration of Task per Day:** Either measured or obtained from plant personnel. Circle the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet: Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate @2-4 hrs; must check w mgmt***)	***Rating Criterion***	***Rating*** (circle)	***Multiplier***
	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	**3**	**0.75**
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
		Duration of Task per Day Multiplier	**0.75**

Table 8 (continued). Insulators Strain Index

Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion **9** x	**Duration of Exertion** **3** x	**Efforts per Minute** **3** x	**Hand/ Wrist Posture** **2** x	**Speed of Work** **1** x	**Duration of Task** **.75**	=	**SI SCORE** **121.5**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:

– SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;

– SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;

– SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;

– SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 9. Insulators UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders (Lifshitz and Armstrong, 1986)
Date/ Time: 10/21/99 Facility: Area/ Shop: Surface Ship in Dry-dock
Task Removal of Insulation Performed by: Steve Wurzelbacher
* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	No	Yes
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges	N	
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?	N	
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	N	
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	N	
6.3 Is the handle of the tool made from material other than metal?	N	
6.4 Is the weight of the tool below 4 kg (9lbs)?		Y
6.5 Is the tool suspended?	N	
TOTAL	18 (82%)	4 (18%)

Table 10. Insulators OWAS

OWAS: OVAKO Work Analysis System (Louhevaara and Suurnäkki, 1992)

Procedure: Observe workers at intervals of 30-60 seconds and record the postures and forces over a representative period (~ 45 minutes)

Date/ Time 10/21/99 Facility Area/ Shop: Surface Ship in Dry-dock
Task: Removal of Insulation Performed by: Steve Wurzelbacher

Risk Factor	**Work Phase 1** **Using small crow-bar to pop off insulating tie caps overhead (standing on ladder)**	**Work Phase 2** **Move ladder**	**Work Phase 3** **Using hawk-bill knife to cut insulation (overhead)**	**Work Phase 4** **Using small crowbar to pry off insulation**	**Work Phase 5** **Resting, talking**	**Work Phase 6** **Pulling insulation off by hand**	**Work Phase 7** **Spraying down insulation with water**
TOTAL Combination Posture Score	***3***	***2***	***2***	***2***	***1***	***2***	***1***
Common Posture Combinations (collapsed across work phases)							
Back	2	2	2	1	1		
Arms	3	1	3	1	3		
Legs	1	7	2	1	2		
Posture Repetition (% of working time)	34	11	58	9	2		
BACK % of Working Time SCORE	***2***	***1***	***2***	***1***	***1***		
ARMS % of Working Time SCORE	***2***	***1***	***2***	***1***	***1***		
LEGS % of Working Time SCORE	***1***	***1***	***1***	***1***	***1***		
ACTION CATEGORIES: ***1 = no corrective measures*** ***2 = corrective measures in the near future*** ***3 = corrective measures as soon as possible*** ***4 = corrective measures immediately***							

Risk Factor	**Work Phase 1** **Using small crow-bar to pop off insulating tie**	**Work Phase 2** **Move ladder**	**Work Phase 3** **Using hawk-bill knife to**	**Work Phase 4** **Using small crowbar to pry off**	**Work Phase 5** **Resting, talking**	**Work Phase 6** **Pulling insulation off by hand**	**Work Phase 7** **Spraying down insulation**

	caps overhead (standing on ladder)		**cut insulation (overhead)**	**insulation**			**with water**
Posture							
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2	2	2	2	1	2	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	3	1	3	3	1	3	3
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	1	7	2	2	1	2	2
Load/ Use of Force							
1 = weight or force needed is = or <10 kg (<22lbs)	2	1	2	2	1	2	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)							
3 = weight or force > 20 kg (>44 lbs)							
Phase Repetition							
% of working time (0,10,20,30,40,50,60,70,80,90,100)	34	11	16	17	9	9	2

Table 10 (continued). Insulators OWAS

Table 11. Insulators PLIBEL

PLIBEL Checklist (Kemmlert, 1995)

Date/ Time: 10/21/99 Facility: Area/ Shop: Surface Ship in Dry-dock
Task: Removal of Insulation Performed by: Steve Wurzelbacher

Section I: Musculoskeletal Risk Factors

Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions (Preferred Method)
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	*Body Regions*				
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	Y	Y	Y	Y	Y
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? E.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 11 (continued). Insulators PLIBEL

10: Is repeated or sustained work performed when the neck is:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	Y				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Notice factors of importance as:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	Y				Y
f) handling below knee length	N				N
g) handling above shoulder height	Y				Y
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		Y			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 11 (continued). Insulators PLIBEL

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
SUM	16	10	3	3	10
PERCENTAGE	61.5	90.9	37.5	37.5	47.6

Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores	
18: Is there no possibility to take breaks and pauses?	N
19: Is there no possibility to choose order and type of work tasks or pace of work	N
20: Is the job performed under time demands or psychological stress	N
21:Can the work have unusual or expected situations?	N
22: Are the following present?	
a) cold	Y
b) heat	Y
c) draft	N
d) noise	Y
e) troublesome visual conditions	N
f) jerks, shakes, or vibration	Y
Environmental / Organizational Risk Factors Score	
SUM	4
PERCENTAGE	40.0

C9.3 Reciprocating Saw Operators

Table 12. Reciprocating Saw Operator RULA

Rapid Upper Limb Assessment (RULA) (Matamney and Corlett, 1993)

Date/Time: 10/21/99 Facility: Area/ Shop: Surface Vessel in Dry-dock
Task : Cutting of Ductwork with Reciprocating Saw Performed by: Steve Wurzelbacher

RULA Component	Frame # 8460 **Sawing sheet metal duct, on floor (man 3, team 2, kneeling, 77% of time)**		Frame # 6720 **Sawing sheet metal duct, on floor (man 3, team 2, standing, 16 % of time)**		Frame # 15090 **Changing saw blade**		Frame # 21540 **Planning cuts to be made, and methods**		Frame # 25050 **Re-positioning workpiece**	
	Specific	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***
Shoulder Extension/ Flexion	sl flex	2	sl flex	2	sl flex	2	sl flex	2	mod flex	3
Shoulder is Raised (+1)		0		0		0		0		0
Upper Arm Abducted (+1)		0		0		0		0		0
Arm supported, leaning (-1)		0		0		-1		-1		0
Elbow Extension/ Flexion	ext	1	neut	2	ext	1	ext	1	ext	1
Shoulder Abduction/ Adduction	add	1	add	1	add	1	neut	0	neut	0
Shoulder Lateral/ Medial	neut	0	neut	0	neut	0	neut	0	med	1
Wrist Extension/ Flexion (left)	ext	2	ext	2	ext	2	neut	1	ext	2
Wrist Deviation	ulnar	1	ulnar	1	ulnar	1	neut	0	neut	0
Wrist Bent from Midline (+1)		0		0		0		0		0
Wrist Twist (1) In mid range **Or** (2) End of range		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		1		0		1
Arm and Wrist Force/ load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or		3		3		1		0		3

repeated or shocks: (+3)										
Neck Extension/ Flexion		3		3		3		2		2
Neck Twist (+1)		0		0		0		0		0
Neck Side-Bent (+1)		0		0		0		0		0
Trunk Extension/ Flexion	sl flex	2	mod flx	3	sl flex	2	sl flex	2	mod flx	3
Trunk Twist (+1)		0		0		0		0		0
Trunk Side Bend (+1)		0		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		1		1		1
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		2		2		2		2
Total RULA Score	**7**		**7**		6		4		**7**	
1 or 2 = ACCEPTABLE **3 or 4 = INVESTIGATE FURTHER** **5 or 6 = INVESTIGATE FURTHER AND CHANGE SOON** **7 = INVESTIGATE AND CHANGE IMMEDIATELY**										

Table 12 (continued). Reciprocating Saw Operator RULA

Table 13. Reciprocating Saw Operator Strain Index

STRAIN INDEX: DISTAL UPPER EXTREMITY (DUE) DISORDERS RISK ASSESSMENT (Moore and Garg, 1995)

LOCATION: Surface Ship in Dry-dock, 10/21/99

TASK: Cutting of Ductwork with Reciprocating Saw

1. **Intensity of Exertion:** An estimate of the strength required to perform the task one time. Circle the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.					
Rating Criterion	***% MS*** (percentage of maximal strength)	***Borg Scale*** (Compare to Borg Cr-10 Scale)	***Perceived Effort***	***Rating*** (circle)	***Multiplier***
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3
Hard	**30 - 49%**	**4 - 5**	**obvious effort; unchanged facial expression (53% of observed time)**	**3**	**6**
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13
				Intensity of Exertion Multiplier	**6**

Table 13 (continued). Reciprocating Saw Operator Strain Index

2. **Duration of Exertion (% of cycle)**: Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.***NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0**

Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
% Duration of Exertion	< 10	1	0.5
= 100 x duration of all exertions (sec) / Total observation time (sec)	10 - 29	2	1.0
	30 - 49	3	1.5
= 100 x 1114 (sec)/ 1224 (sec) = 91	50 -79	4	2.0
	> or = 80	**5**	**3.0**
		Duration of Exertion Multiplier	**3.0**

3. **Efforts per Minute:** Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. ***NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0**

Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
Efforts per Minute	< 4	1	0.5
= number of exertions / Total observation time (min)	4 - 8	2	1.0
	9 -14	3	1.5
= nearly static exertion, therefore **multiplier = 3**	15 -19	4	2.0
	> or = 20	**5**	**3.0**
		Efforts per Minute Multiplier	**3.0**

Table 13 (continued). Reciprocating Saw Operator Strain Index

4. **Hand/ Wrist Posture:** An estimate of the position of the hand or wrist relative to neutral position. Circle the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	***Wrist Extension*** (Stetson et al, 1991)	***Wrist Flexion*** (Stetson et al, 1991	***Ulnar Deviation*** (Stetson et al, 1991	***Perceived Posture***	***Rating*** (circle)	***Multiplier***
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral	3	1.5
Bad	**41 - 55 degrees**	**31 - 50 degrees**	**21 -25 degrees**	**marked deviation (*estimated, based on RULAs performed)**	**4**	**2.0**
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
					Hand/ Wrist Posture Multiplier	**2.0**

Table 13 (continued). Reciprocating Saw Operator Strain Index

5. **Speed of Work:** An estimate of how fast the worker is working. Circle the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	***Compared to MTM*** -1 (observed pace is divided by MTM's predicted pace and expressed as % ; See Barnes 1980)	***Perceived Speed***	***Rating*** (circle)	***Multiplier***
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	**91 -100%**	**"normal" speed of motion**	**3**	**1.0**
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed and barely or unable to keep up	5	2.0
			Speed of Work Multiplier	**1.0**

6. **Duration of Task per Day:** Either measured or obtained from plant personnel. Circle the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet: Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate @2-4 hrs; must check w mgmt***)	***Rating Criterion***	***Rating*** (circle)	***Multiplier***
	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	**3**	**0.75**
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
		Duration of Task per Day Multiplier	**0.75**

Table 13 (continued). Reciprocating Saw Operator Strain Index

Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion **6 x**	**Duration of Exertion** **3 x**	**Efforts per Minute** **3 x**	**Hand/ Wrist Posture** **2 x**	**Speed of Work** **1 x**	**Duration of Task** **.75**	**=**	**SI SCORE** **81**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:

– SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;

– SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;

– SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;

– SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 14. Reciprocating Saw Operator UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders (Lifshitz and Armstrong, 1986)

Date/ Time: 10/21/99 Facility: Area/ Shop: Surface Ship in Dry-dock
Task Cutting of Ductwork by Reciprocating Saw Performed by: Steve Wurzelbacher
* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	No	Yes
1**. Physical Stress**		
1.1 Can the job be done without hand/ wrist contact with sharp edges	N	
1.2 Is the tool operating without vibration?	N	
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?		Y
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	N (Pistol grip)	
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	N (left hand)	
6.3 Is the handle of the tool made from material other than metal?		Y
6.4 Is the weight of the tool below 4 kg (9lbs)?		Y
6.5 Is the tool suspended?	N	
TOTAL	16 (73%)	6 (27%)

Table 15. Reciprocating Saw Operator OWAS

OWAS: OVAKO Work Analysis System (Louhevaara and Suurnäkki, 1992)

Procedure: Observe workers at intervals of 30-60 seconds and record the postures and forces over a representative period (~ 45 minutes)

Date/ Time 10/21/99 Facility Area/ Shop: Surface Ship in Dry-dock
Task: Cutting of Ductwork with Reciprocating Saw Performed by: Steve Wurzelbacher

Risk Factor	**Work Phase 1** Sawing sheet-metal duct, on floor (man 3, team 2)	**Work Phase 2** Re-position-ing saw	**Work Phase 3** Sawing sheet-metal duct, on floor (man 4, team 2)	**Work Phase 4** Re-position-ing body	**Work Phase 5** Transfer saw from person to person	**Work Phase 6** Planning cuts to be made, and methods	**Work Phase 7** Re-position-ing work-piece	**Work Phase 8** Chang-ing saw blade
TOTAL Combination Posture Score	***2***	***2***	***2***	***2***	***1***	***1***	***2***	***2***
Common Posture Combinations (collapsed across work phases)								
Back	2	1						
Arms	1	1						
Legs	6	6						
Posture Repetition (% of working time)	84	13						
BACK % of Working Time SCORE	***3***	***1***						
ARMS % of Working Time SCORE	***1***	***1***						
LEGS % of Working Time SCORE	***3***	***1***						
ACTION CATEGORIES: ***1 = no corrective measures*** ***2 = corrective measures in the near future*** ***3 = corrective measures as soon as possible*** ***4 = corrective measures immediately***								
	Work	**Work**	**Work**	**Work**	**Work**	**Work**	**Work**	**Work**

Risk Factor	Phase 1 Sawing sheet-metal duct, on floor (man 3, team 2, kneeling 77% of time))	Phase 2 Re-position-ing saw	Phase 3 Sawing sheet-metal duct, on floor (man 4, team 2)	Phase 4 Re-position-ing body	Phase 5 Transfer saw from person to person	Phase 6 Planning cuts to be made, and methods	Phase 7 Re-position-ing work-piece	Phase 8 Chang-ing saw blade
Posture								
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2	2	2	2	1	1	2	2
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	2, 6	6	6	6	6	6	6	6
Load/ Use of Force								
1 = weight or force needed is = or <10 kg (<22lbs)	2	1	2	2	1	1	3	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)								
3 = weight or force > 20 kg (>44 lbs)								
Phase Repetition								
% of working time (0,10,20,30,40,50,60,70,80,90,100)	50	4	8	3	1	12	6	13

Table 15 (continued). Reciprocating Saw Operator OWAS

Table 16. Reciprocating Saw Operator NIOSH Manual Materials Handling Checklist

NIOSH Hazard Evaluation Checklist for Lifting, Carrying, Pushing, or Pulling (Waters and Putz-Anderson, 1996)

Date/ Time 10/21/99 Facility __ Area/ Shop: Surface Ship in Dry-dock
Task: Cutting of Ductwork with Reciprocating Saw Performed by: Steve Wurzelbacher

RISK FACTORS	YES	NO
General		
1.1 Does the load handled exceed 50 lbs?		N
1.2 Is the object difficult to bring close to the body because of it's size, bulk, or shape?	Y	
1.3 Is the load hard to handle because it lacks handles or cutouts for handles, or does it have slippery surfaces or sharp edges?	Y	
1.4 Is the footing unsafe? For example, are the floors slippery, inclined, or uneven?		N
1.5 Does the task require fast movement, such as throwing, swinging, or rapid walking?		N
1.6 Does the task require stressful body postures such as stooping to the floor, twisting, reaching overhead, or excessive lateral bending?	Y (extended kneeling)	
1.7 Is most of the load handled by only one hand, arm, or shoulder?		N
1.8 Does the task require working in environmental hazards, such as extreme temperatures, noise, vibration, lighting, or airborne contamination?	Y (full body PPE)	
1.9 Does the task require working in a confined area?		N
Specific		
2.1 Does the lifting frequency exceed 5 lifts per minute (LPM)?		N
2.2 Does the vertical lifting distance exceed 3 feet?		N
2.3 Do carries last longer than 1 minute?		N
2.4 Do tasks which require large sustained pushing or pulling forces exceed 30 seconds duration?	Y (holding sawsall)	
2.5 Do extended reach static holding tasks exceed 1 minute?	Y (holding sawsall)	
TOTAL	6 (43%)	8 (57%)

* "YES" responses are indicative of conditions that pose a risk of developing low back pain; the larger the percentage of "YES" responses, the greater the risk.

Table 17. Reciprocating Saw Operator PLIBEL

PLIBEL Checklist (Kemmlert, 1995)

Date/ Time: 10/21/99 Facility: Area/ Shop: Surface Ship in Dry-dock
Task: Cutting Ductwork with Reciprocating Saw Performed by: Steve Wurzelbacher

Section I: Musculoskeletal Risk Factors

Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions (Preferred Method)
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	*Body Regions*				
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
1: Is the walking surface uneven, sloping, slippery or nonresilient?			N	N	N
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? E.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			Y	Y	Y
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 17 (continued). Reciprocating Saw Operator PLIBEL

10: Is repeated or sustained work performed when the neck is:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Notice factors of importance as:					
a) periods of repetitive lifting	N				N
b) weight of load	Y				Y
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	Y				Y
e) handling beyond forearm length	Y				Y
f) handling below knee length	Y				Y
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		Y			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 17 (continued). Reciprocating Saw Operator PLIBEL

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
SUM	17	9	2	2	12
PERCENTAGE	65.4	81.8	25.0	25.0	57.1
Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work	N				
20: Is the job performed under time demands or psychological stress	N				
21:Can the work have unusual or expected situations?	Y				
22: Are the following present?					
a) cold	Y				
b) heat	Y				
c) draft	N				
d) noise	Y				
e) troublesome visual conditions	N				
f) jerks, shakes, or vibration	Y				
Environmental / Organizational Risk Factors Score					
SUM	5				
PERCENTAGE	50.0				

C9.4 Tile Chipper

Table 18. Tile Chipper RULA

Rapid Upper Limb Assessment (RULA) (Matamney and Corlett, 1993)

Date/Time: 10/21/99 Facility Area/ Shop: Surface Vessel in Dry-dock
Task : Removing Terrazzo Tile from Floor with Chipping Hammer Performed by: Steve Wurzelbacher

RULA Component	Frame # 37290 chipping (blade perpendicular to tile)		Frame # 38489 chipping (blade parallel to tile)		Frame # 39960 re-positioning chipper		Frame # 41520 brush away, remove loose tile		Frame # 41520 re-positioning body	
	Specific	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*
Shoulder Extension/ Flexion	sl flex	2	sl flex	2	sl flex	2	sl flex	2	sl flex	2
Shoulder is Raised (+1)		1		0		0		0		0
Upper Arm Abducted (+1)		1		0		0		0		0
Arm supported, leaning (-1)		-1		-1		-1		0		0
Elbow Extension/ Flexion	flx	2	ext	1	neut	2	ext	1	ext	1
Shoulder Abduction/ Adduction	mod abd	1	add	1	neut	0	neut	0	neut	0
Shoulder Lateral/ Medial	lat	1	lat	1	neut	0	neut	0	neut	0
Wrist Extension/ Flexion (left)	neut	1	flx	2	ext	2	ext	2	ext	2
Wrist Deviation	ulnar	1	ulnar	1	ulnar	1	neut	0	neut	0
Wrist Bent from Midline (+1)		0		0		0		0		0
Wrist Twist (1) In mid range Or (2) End of range		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		1		0		0
Arm and Wrist Force/ load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks:		3		3		1		0		0

(+3)										
Neck Extension/ Flexion		**3**		**3**		**3**		**3**		**3**
Neck Twist (+1)		**1**		**1**		**1**		**1**		**1**
Neck Side-Bent (+1)		**0**		**0**		**0**		**0**		**0**
Trunk Extension/ Flexion	**mod flx**	**3**	**hyp flx**	**4**	**mod flx**	**3**	**mod flx**	**3**	**mod flx**	**3**
Trunk Twist (+1)		**0**		**0**		**0**		**0**		**0**
Trunk Side Bend (+1)		**0**		**0**		**0**		**0**		**0**
Legs **If legs and feet are supported and balanced: (+1);** **If not: (+2)**		**1**		**1**		**1**		**1**		**1**
Neck, Trunk, and Leg Muscle Use Score **If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)**		**1**		**1**		**1**		**1**		**1**
Neck, Trunk, and Leg Force/ Load Score **If load less than 2 kg (intermittent): (+0)** **If 2kg to 10 kg (intermittent): (+1)** **If 2kg to 10 kg (static or repeated): (+2)** **If more than 10 kg load or repeated or shocks: (+3)**		**2**		**2**		**2**		**2**		**2**
Total RULA Score	**7**		**7**		**7**		3		3	
1 or 2 = ACCEPTABLE **3 or 4 = INVESTIGATE FURTHER** **5 or 6 = INVESTIGATE FURTHER AND CHANGE SOON** **7 = INVESTIGATE AND CHANGE IMMEDIATELY**										

Table 18 (continued). Tile Chipper RULA

Table 19. Tile Chipper Strain Index

STRAIN INDEX: DISTAL UPPER EXTREMITY (DUE) DISORDERS RISK ASSESSMENT
(Moore and Garg, 1995)

LOCATION: Surface Ship in Dry-dock, 10/21/99

TASK: Chipping Terrazzo Tile from Deck with Chipping Hammer

1. **Intensity of Exertion:** An estimate of the strength required to perform the task one time. Circle the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.					
Rating Criterion	***% MS*** (percentage of maximal strength)	***Borg Scale*** (Compare to Borg Cr-10 Scale)	***Perceived Effort***	***Rating*** (circle)	***Multiplier***
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3
Hard	**30 - 49%**	**4 - 5**	**obvious effort; unchanged facial expression (66% of observed time hard)**	**3**	**6**
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13
				Intensity of Exertion Multiplier	**6**

Table 19 (continued). Tile Chipper Strain Index

2. **Duration of Exertion (% of cycle)**: Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.***NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0**

Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
% Duration of Exertion	< 10	1	0.5
= 100 x duration of all exertions (sec) / Total observation time (sec)	10 - 29	2	1.0
	30 - 49	3	1.5
= 100 x 252 (sec)/ 278 (sec) = 91	50 -79	4	2.0
	> or = 80	**5**	**3.0**
		Duration of Exertion Multiplier	**3.0**

3. **Efforts per Minute:** Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. ***NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0**

Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
Efforts per Minute	< 4	1	0.5
= number of exertions / Total observation time (min)	4 - 8	2	1.0
	9 -14	3	1.5
=(58/4.6min) = 12.5, but nearly static exertion, therefore compromise and set **multiplier = 2**	**15 -19**	**4**	**2.0**
	> or = 20	5	3.0
		Efforts per Minute Multiplier	**2.0**

Table 19 (continued). Tile Chipper Strain Index

4. **Hand/ Wrist Posture:** An estimate of the position of the hand or wrist relative to neutral position. Circle the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	***Wrist Extension*** (Stetson et al, 1991)	***Wrist Flexion*** (Stetson et al, 1991	***Ulnar Deviation*** (Stetson et al, 1991	***Perceived Posture***	***Rating*** (circle)	***Multiplier***
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral	3	1.5
Bad	**41 - 55 degrees**	**31 - 50 degrees**	**21 -25 degrees**	**marked deviation (*estimated, based on RULAs performed)**	**4**	**2.0**
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier (Fill in)						**2.0**

Table 19 (continued). Tile Chipper Strain Index

5. **Speed of Work:** An estimate of how fast the worker is working. Circle the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	***Compared to MTM*** -1 (observed pace is divided by MTM's predicted pace and expressed as % ; See Barnes 1980)	***Perceived Speed***	***Rating*** (circle)	***Multiplier***
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	**91 -100%**	**"normal" speed of motion**	**3**	**1.0**
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed and barely or unable to keep up	5	2.0
			Speed of Work Multiplier	**1.0**

6. **Duration of Task per Day:** Either measured or obtained from plant personnel. Circle the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	***Rating Criterion***	***Rating*** (circle)	***Multiplier***
Duration of Task per Day (hrs)	< or = 1 hrs	1	0.25
= duration of task (hrs) + duration of task (hrs) + ...	1 - 2 hrs	2	0.50
= (estimate @2-4 hrs; must check w	**2 - 4 hrs**	**3**	**0.75**
mgmt***)	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
		Duration of Task per Day Multiplier	**0.75**

Table 19 (continued). Tile Chipper Strain Index

Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion **6 x**	**Duration of Exertion** **3 x**	**Efforts per Minute** **2 x**	**Hand/ Wrist Posture** **2 x**	**Speed of Work** **1 x**	**Duration of Task** **.75 x**	**=**	**SI SCORE** **54**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:

– SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;

– SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;

– SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;

– SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 20. Tile Chipper UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders (Lifshitz and Armstrong, 1986)

Date/ Time: 10/21/99 Facility: Area/ Shop: Surface Ship in Dry-dock
Task Chipping Terrazzo Tile from Deck with Chipping Hammer Performed by: Steve Wurzelbacher
* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	**No**	**Yes**
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?	N	
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	N	
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?		Y
6.3 Is the handle of the tool made from material other than metal?	N	
6.4 Is the weight of the tool below 4 kg (9lbs)?	N (estimated)	
6.5 Is the tool suspended?	N	
TOTAL	17 (77 %)	5 (23%)

Table 21. Tile Chipper OWAS

OWAS: OVAKO Work Analysis System (Louhevaara and Suurnäkki, 1992)

Procedure: Observe workers at intervals of 30-60 seconds and record the postures and forces over a representative period (~ 45 minutes)

Date/ Time 10/21/99 Facility Area/ Shop: Surface Ship in Dry-dock
Task: Chipping Terrazzo Tile from Deck with Chipping Hammer Performed by: Steve Wurzelbacher

Risk Factor	**Work Phase 1** **Chipping (blade perpendicular to tile)**	**Work Phase 2** **Re-positioning chipper**	**Work Phase 3** **Chipping (blade parallel to tile)**	**Work Phase 4** **Re-positioning body**	**Work Phase 5** **Brush away, remove loose tile**	**Work Phase 6** **Rest Break**
TOTAL Combination Posture Score	***2***	***2***	***2***	***2***	***2***	***1***
Common Posture Combinations (collapsed across work phases)						
Back	2	1				
Arms	1	1				
Legs	6	7				
Posture Repetition (% of working time)	91	9				
BACK % of Working Time SCORE	***3***	***1***				
ARMS % of Working Time SCORE	***1***	***1***				
LEGS % of Working Time SCORE	***3***	***1***				
ACTION CATEGORIES: ***1 = no corrective measures*** ***2 = corrective measures in the near future*** ***3 = corrective measures as soon as possible*** ***4 = corrective measures immediately***						
Risk Factor	**Work Phase 1** **Chipping**	**Work Phase 2** **Re-**	**Work Phase 3** **Chipping**	**Work Phase 4** **Re-**	**Work Phase 5** **Brush**	**Work Phase 6** **Rest**

	(blade perpendicular to tile)	positioning chipper	(blade parallel to tile)	positioning body	away, remove loose tile	Break
Posture						
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2	2	2	2	2	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	6	6	6	6	6	7
Load/ Use of Force						
1 = weight or force needed is = or <10 kg (<22lbs)	2	2	2	2	1	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)						
3 = weight or force > 20 kg (>44 lbs)						
Phase Repetition						
% of working time (0,10,20,30,40,50,60,70,80,90,100)	8	11	58	4	10	9

Table 21 (continued). Tile Chipper OWAS

Table 22. Tile Chipper NIOSH Manual Materials Handling Checklist

NIOSH Hazard Evaluation Checklist for Lifting, Carrying, Pushing, or Pulling (Waters and Putz-Anderson, 1996)

Date/ Time 10/21/99 Facility Area/ Shop: Surface Ship in Dry-dock
Task: Chipping Terrazzo Tile Off Deck with Chipping Hammer Performed by: Steve Wurzelbacher

RISK FACTORS	YES	NO
General		
1.1 Does the load handled exceed 50 lbs?		N
1.2 Is the object difficult to bring close to the body because of its size, bulk, or shape?	Y	
1.3 Is the load hard to handle because it lacks handles or cutouts for handles, or does it have slippery surfaces or sharp edges?	Y	
1.4 Is the footing unsafe? For example, are the floors slippery, inclined, or uneven?		N
1.5 Does the task require fast movement, such as throwing, swinging, or rapid walking?		N
1.6 Does the task require stressful body postures such as stooping to the floor, twisting, reaching overhead, or excessive lateral bending?	Y (extended kneeling))	
1.7 Is most of the load handled by only one hand, arm, or shoulder?		N
1.8 Does the task require working in environmental hazards, such as extreme temperatures, noise, vibration, lighting, or airborne contamination?	Y (outside, vibration)	
1.9 Does the task require working in a confined area?		N
Specific		
2.1 Does the lifting frequency exceed 5 lifts per minute (LPM)?		N
2.2 Does the vertical lifting distance exceed 3 feet?		N
2.3 Do carries last longer than 1 minute?		N
2.4 Do tasks which require large sustained pushing or pulling forces exceed 30 seconds duration?	Y (holding chipper)	
2.5 Do extended reach static holding tasks exceed 1 minute?	Y (holding chipper)	
TOTAL	6 (43%)	8 (57%)

* "YES" responses are indicative of conditions that pose a risk of developing low back pain; the larger the percentage of "YES" responses, the greater the risk.

Table 23. Tile Chipper PLIBEL

PLIBEL Checklist (Kemmlert, 1995)

Date/ Time: 10/21/99 Facility: Area/ Shop: Surface Ship in Dry-dock
Task: Chipping Terrazzo Tile from Deck with Chipping Hammer Performed by: Steve Wurzelbacher

Section I: Musculoskeletal Risk Factors

Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions (Preferred Method)
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	*Body Regions*				
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
1: Is the walking surface uneven, sloping, slippery or nonresilient?			N	N	N
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? E.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			Y	Y	Y
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 23 (continued). Tile Chipper PLIBEL

10: Is repeated or sustained work performed when the neck is:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	Y				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Notice factors of importance as:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	Y				Y
f) handling below knee length	Y				Y
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		Y			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 23 (continued). Tile Chipper PLIBEL

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
SUM	16	9	2	2	10
PERCENTAGE	61.5	81.8	25.0	25.0	47.1

Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores	
18: Is there no possibility to take breaks and pauses?	N
19: Is there no possibility to choose order and type of work tasks or pace of work	N
20: Is the job performed under time demands or psychological stress	N
21:Can the work have unusual or expected situations?	N
22: Are the following present?	
a) cold	Y
b) heat	Y
c) draft	Y
d) noise	Y
e) troublesome visual conditions	N
f) jerks, shakes, or vibration	Y
Environmental / Organizational Risk Factors Score	
SUM	5
PERCENTAGE	50.0

C9.5 "Cut and Carry" Worker

Table 24. "Cut and Carry" Worker Strain Index

STRAIN INDEX: DISTAL UPPER EXTREMITY (DUE) DISORDERS RISK ASSESSMENT
(Moore and Garg, 1995)

LOCATION: Surface Ship in Dry-dock, 10/21/99

TASK: Carry Material by Hand in Ship Dismantling

1. **Intensity of Exertion:** An estimate of the strength required to perform the task one time. Circle the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.					
Rating Criterion	***% MS*** (percentage of maximal strength)	***Borg Scale*** (Compare to Borg Cr-10 Scale)	***Perceived Effort***	***Rating*** (circle)	***Multiplier***
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1
Somewhat hard	**10 - 29%**	**3**	**noticeable or definite effort (38% light, 33% somewhat hard, 28% hard)**	**2**	**3**
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13
				Intensity of Exertion Multiplier	**3**

Table 24 (continued). "Cut and Carry" Worker Strain Index

2. **Duration of Exertion (% of cycle)**: Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.***NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0**

Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
% Duration of Exertion	< 10	1	0.5
= 100 x duration of all exertions (sec) / Total observation time (sec)	10 - 29	2	1.0
	30 - 49	**3**	**1.5**
= 100 x 556 (sec)/ 1162 (sec) = 48	50 -79	4	2.0
	> or = 80	5	3.0
		Duration of Exertion Multiplier	**1.5**

3. **Efforts per Minute:** Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. ***NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0**

Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
Efforts per Minute	**< 4**	**1**	**0.5**
= number of exertions / Total observation time (min)	4 - 8	2	1.0
	9 -14	3	1.5
= [total # of efforts for observed period, 69/ Total observed time (min) 19.37]	15 -19	4	2.0
= 3.56	> or = 20	5	3.0
		Efforts per Minute Multiplier	**0.5**

Table 24 (continued). "Cut and Carry" Worker Strain Index

4. **Hand/ Wrist Posture:** An estimate of the position of the hand or wrist relative to neutral position. Circle the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	***Wrist Extension*** (Stetson et al, 1991)	***Wrist Flexion*** (Stetson et al, 1991	***Ulnar Deviation*** (Stetson et al, 1991	***Perceived Posture***	***Rating*** (circle)	***Multiplier***
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	**26 -40 degrees**	**16 - 30 degrees**	**16 - 20 degrees**	**non-neutral (*estimated, no RULA performed)**	**3**	**1.5**
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
					Hand/ Wrist Posture Multiplier (Fill in)	**1.5**

Table 24 (continued). "Cut and Carry" Worker Strain Index

5. **Speed of Work:** An estimate of how fast the worker is working. Circle the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	***Compared to MTM*** -1 (observed pace is divided by MTM's predicted pace and expressed as % ; See Barnes 1980)	***Perceived Speed***	***Rating*** (circle)	***Multiplier***
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	**91 -100%**	**"normal" speed of motion**	**3**	**1.0**
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed and barely or unable to keep up	5	2.0
			Speed of Work Multiplier	**1.0**

6. **Duration of Task per Day:** Either measured or obtained from plant personnel. Circle the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	***Rating Criterion***	***Rating*** (circle)	***Multiplier***
Duration of Task per Day (hrs)	< or = 1 hrs	1	0.25
= duration of task (hrs) + duration of task (hrs) + ...	1 - 2 hrs	2	0.50
= (estimate @4 hrs; must check w	**2 - 4 hrs**	**3**	**0.75**
mgmt***)	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
		Duration of Task per Day Multiplier	**0.75**

Table 24 (continued). "Cut and Carry" Worker Strain Index

Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion **3 x**	**Duration of Exertion** **1.5 x**	**Efforts per Minute** **0.5 x**	**Hand/ Wrist Posture** **1.5 x**	**Speed of Work** **1 x**	**Duration of Task** **.75**	**=**	**SI SCORE** **2.5**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:

– SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;

– SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;

– SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;

– SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 25. "Cut and Carry" Worker UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders (Lifshitz and Armstrong, 1986)

Date/ Time: 10/21/99 Facility: Area/ Shop: Surface Ship in Dry-dock
Task Carrying Material by Hand in Ship Dismantling Performed by: Steve Wurzelbacher
* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	**No**	**Yes**
1**. Physical Stress**		
1.1 Can the job be done without hand/ wrist contact with sharp edges	N	
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N/A	N/A
3.3 Can the job be done without deviating the wrist from side to side?		Y
3.4 Can the tool be used without deviating the wrist from side to side?		Y
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N/A	N/A
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	N/A	N/A
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	N/A	N/A
6.3 Is the handle of the tool made from material other than metal?	N/A	N/A
6.4 Is the weight of the tool below 4 kg (9lbs)?	N/A	N/A
6.5 Is the tool suspended?	N/A	N/A
TOTAL	9 (60%)	6 (40%)

Table 26. "Cut and Carry" Worker OWAS

OWAS: OVAKO Work Analysis System (Louhevaara and Suurnäkki, 1992)

Procedure: Observe workers at intervals of 30-60 seconds and record the postures and forces over a representative period (~ 45 minutes)

Date/ Time 10/21/99 Facility Area/ Shop: Surface Ship in Dry-dock
Task: Carrying Material by Hand in Ship Dismantling Performed by: Steve Wurzelbacher

	Work Phase 1: Tandem carrying material to bin	**Work Phase 2 Single carrying material to bin**	**Work Phase 3 Bin arranging**	**Work Phase 4 Brigade carrying material to bin**	**Work Phase 5 Lifting material off pile**	**Work Phase 6 Walking back and forth**	**Work Phase 7 Waiting for crane, resting**
TOTAL Combination Posture Score	***1***	***1***	***2***	***1***	***2***	***1***	***1***
Common Posture Combinations (collapsed across work phases)							
Back	1	2	4	1			
Arms	1	1	1	1			
Legs	7	2	2	2			
Posture Repetition (% of working time)	22	7	23	18			
BACK % of Working Time SCORE	***1***	***1***	***2***	***1***			
ARMS % of Working Time SCORE	***1***	***1***	***1***	***1***			
LEGS % of Working Time SCORE	***1***	***1***	***1***	***1***			
ACTION CATEGORIES: ***1 = no corrective measures*** ***2 = corrective measures in the near future*** ***3 = corrective measures as soon as possible*** ***4 = corrective measures immediately***							
Risk Factor	**Work Phase 1:**	**Work Phase 2**	**Work Phase 3**	**Work Phase 4**	**Work Phase 5**	**Work Phase 6**	**Work Phase 7**

	Tandem carrying material to bin	Single carrying material to bin	Bin arrange-ing	Brigade carrying material to bin	Lifting material off pile	Walking back and forth	Waiting for crane, resting
Posture							
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	1	1	2	1	4	1	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	7	7	2	7	2,7	7	2
Load/ Use of Force							
1 = weight or force needed is = or <10 kg 2 = weight or force > 10 but < 20kg 3 = weight or force > 20 kg	2	2	2	2	2,3	1	1
Phase Repetition							
% of working time (0,10,20,30,40,50,60,70,80,90,100)	10	2	7	5	23	5	18

Table 26 (continued). “Cut and Carry” Worker OWAS

Table 27. "Cut and Carry" Worker NIOSH Manual Materials Handling Checklist

NIOSH Hazard Evaluation Checklist for Lifting, Carrying, Pushing, or Pulling (Waters and Putz-Anderson, 1996)

Date/ Time 10/21/99 Facility Area/ Shop: Surface Ship in Dry-dock
Task: Carrying Material by Hand in Ship Dismantling Performed by: Steve Wurzelbacher

RISK FACTORS	YES	NO
General		
1.1 Does the load handled exceed 50 lbs?		N (usually not)
1.2 Is the object difficult to bring close to the body because of it┗═ size, bulk, or shape?	Y	
1.3 Is the load hard to handle because it lacks handles or cutouts for handles, or does it have slippery surfaces or sharp edges?	Y	
1.4 Is the footing unsafe? For example, are the floors slippery, inclined, or uneven?	Y	
1.5 Does the task require fast movement, such as throwing, swinging, or rapid walking?		N
1.6 Does the task require stressful body postures such as stooping to the floor, twisting, reaching overhead, or excessive lateral bending?	Y (lumbar flexion)	
1.7 Is most of the load handled by only one hand, arm, or shoulder?		N
1.8 Does the task require working in environmental hazards, such as extreme temperatures, noise, vibration, lighting, or airborne contamination?		N (cold, heat occasionally)
1.9 Does the task require working in a confined area?	Y	
Specific		
2.1 Does the lifting frequency exceed 5 lifts per minute (LPM)?		N (LPM = 3.4 over total cycle time)
2.2 Does the vertical lifting distance exceed 3 feet?		N
2.3 Do carries last longer than 1 minute?		N
2.4 Do tasks which require large sustained pushing or pulling forces exceed 30 seconds duration?		N (usually @ 5-10)
2.5 Do extended reach static holding tasks exceed 1 minute?		N
TOTAL	5 (36%)	9 (64%)

* "YES" responses are indicative of conditions that pose a risk of developing low back pain; the larger the percentage of "YES" responses, the greater the risk.

Table 28. "Cut and Carry" Worker 3D Static Strength Prediction Program

3D Static Strength Prediction Program (University of Michigan, 1997)

Date/ Time: 10/21/99 *Facility:*
Area/ Shop: Surface Vessel in Dry-dock for Dismantling *Task:* Carrying Material by Hand

Work Element:	**Disc Compression (lbs) @ L5/S1** (Note: NIOSH Recommended Compression Limit (RCL) is 770 lbs.)
Lifting a 40 pound item out of a scrap bin, two-handed	741.4 lbs.
Pulling a 40 pound item out of a scrap pile, two-handed	501.0 lbs.
Lifting a 20 pound item off a scrap pile, one-handed	549.7 lbs.
Tandem lift of 40 pound item (20 pounds per person), each two-handed	311.8 lbs.

Table 29. "Cut and Carry" Worker PLIBEL

PLIBEL Checklist (Kemmlert, 1995)

Date/ Time: 10/21/99 Facility
Area/ Shop: Surface Vessel in Dry-dock for Dismantling
Task: Carrying Material by Hand Performed by: Steve Wurzelbacher

Section I: Musculoskeletal Risk Factors Methods of Application: 1) Find the injured body region, answer yes or no to corresponding questions (Preferred Method) 2) Answer questions, score potential body regions for injury risk					
Musculoskeletal Risk Factor Questions	*Body Regions*				
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	Y	Y	Y	Y	Y
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			Y	Y	Y
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? E.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	Y				Y
d) severely twisted?	N				N

Table 29 (continued). "Cut and Carry" Worker PLIBEL

10: Is repeated or sustained work performed when the neck is:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Notice factors of importance as:					
a) periods of repetitive lifting	Y				Y
b) weight of load	N				N
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	Y				Y
e) handling beyond forearm length	Y				Y
f) handling below knee length	Y				Y
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	N				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	N	N			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		Y			
c) uncomfortable hand positions?		N			
d) switches or keyboards?		N			

Table 29 (continued). "Cut and Carry" Worker PLIBEL

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
SUM	16	7	4	4	14
PERCENTAGE	61.5	63.6	50	50	66.7

Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores	
18: Is there no possibility to take breaks and pauses?	N
19: Is there no possibility to choose order and type of work tasks or pace of work	N
20: Is the job performed under time demands or psychological stress	N
21:Can the work have unusual or expected situations?	N
22: Are the following present?	
a) cold	Y
b) heat	Y
c) draft	Y
d) noise	Y
e) troublesome visual conditions	N
f) jerks, shakes, or vibration	N
Environmental / Organizational Risk Factors Score	
SUM	4
PERCENTAGE	40.0

APPENDIX D

PRE-INTERVENTION QUALITATIVE ERGONOMIC HAZARD ANALYSIS

WORK TASKS ANALYZED:

Pipe welding

Torch cutting

Waterjet blasting

Grinding

Welding operations

D1. PIPE WELDING ONBOARD VESSEL

Figure 3. Pipefitter Welding Task

D1.1. Pipe Welding Process

Numerous pipe connections may be required in any repair task. Pipefitters piece together the piping subassemblies and weld them into place. The overall pipe welding process is as follows:

1) Pipefitter gets into position to weld pipe together. This may involve working in a confined space, working from an elevated surface, and/or working overhead.

Figure 4. Pipefitter Getting Into Position to Weld

2) Using stick electrodes and equipment, weld pipes into proper position.

Figure 5. Pipefitter Welding Pipe Onboard Vessel

3) If stick electrode is consumed before weld is finished, pipefitter must change out the stick electrode.

Figure 6. Pipefitter Changing Out Stick Electrode

4) After weld is completed, the pipefitter removes the slag from the weld by knocking the slag off with a hammer.

Figure 7. Pipefitter Removing Weld Slag with Hammer

5) Finally, the pipefitter grinds the weld smooth using a small angle grinder.

Figure 8. Pipefitter Using Angle Grinder to Smooth Weld

D1.2. Pipe Welding Ergonomic Risk Factors

During pipe welding task, pipefitters undergo awkward postures including lumbar flexion and extension, overhead work, and static postures. Pipefitters undertake a variety of awkward postures such as extreme lumbar flexion, shoulder abduction, wrist flexion, both ulnar and radial deviation, and working in confined spaces.

D1.3. Ergonomic Analysis of Pipefitters in Pipe Welding Process

Using several of the exposure assessment tools outlined above, an ergonomic analysis was performed for the pipefitter in the pipe welding task. A RULA analysis was performed on six distinct subtasks within the pipe welding activity (D9.1 Table 1). Three of the six subtasks scored a 6 on a scale of 1 to 7 (investigate further and change soon). The subtasks included welding overhead, deslagging the weld with a hammer and grinding the weld smooth with an electric angle grinder. Two other subtasks, changing the stick electrode and changing the tool, resulted in score of 3 (investigate further). The final subtask of getting into position to weld was deemed “acceptable” with a score of two out of seven.

A Strain Index analysis was performed for the overhead pipe welding activity (D9.1 Table 2) with the following results:

1) the Intensity of Exertion was rated as “Somewhat Hard” and given a multiplier score of 3.0 on a scale of 1 to 13
2) the Duration of the task was rated as 50 - 79 per cent of the task cycle, resulting in a multiplier of 2.0 on a scale of 0.5 to 3.0
3) the Efforts per Minute were noted to be approximately 2.2 per minute, resulting in a multiplier of 0.5 on a scale of 0.5 to 3.0
4) the Hand/Wrist posture was rated as “Fair,” resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0
5) the Speed of Work was rated as “Fair,” resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
6) the Duration of Task per Day was rated to be between 2 and 4 hours, resulting in a multiplier of 0.75 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 3.4. An SI score less than 5 is correlated to an incidence rate of about 2 distal upper extremity injuries per 100 FTE.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the pipe welding task (D9.1 Table 3), of the 21 possible responses, 13 were negative, five were positive, and three were answered both negatively and positively depending upon the situation observed. Negative responses (69 percent) are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the pipe welding task (D9.1 Table 4), “corrective measures in the near future” were suggested for only two of eight specific sub-tasks, those scoring a 2 on a 4-point scale. These sub-tasks were deslagging and changing tools. Analysis of the other six subtasks resulted in a score of 1 out of 4, suggesting no corrective measures were necessary.

The PLIBEL checklist for the pipe welding task (D9.1 Table 5) reports low to moderate percentages (34.6 - 50 percent) of risk factors present for the any given part of body. Several environmental and organizational modifying factors are present as well that can be considered in future analysis.

D2. TORCH CUTTING ONBOARD VESSEL

Figure 9. Torch Cutting of Steel Deck

D2.1. Torch Cutting Process

There are many circumstances in ship repair processes when torch cutting is used to remove steel decking or bulkheads (Figure 9). At times individual components scheduled for replacement are located in such confined spaces that it is easier to torch cut an opening either besides, above or below an item in order to remove it from its original location. At other times, the physical dimensions of compartments are slated to change for one reason or another, again calling for the removal of decking or bulkheads. The torch cutting process involves the following steps:

Figure 10. Adjusting Torch Flame

1) Lighting the cutting torch and adjust the flame (Figure 10)

2) Cutting the deck or bulkhead (See Figure 9 above)

Figure 11. Brushing Debris from Cut Line

3) Brushing debris away from cut line to improve line of sight (Figure 11)

Figure 12. Worker Resting Between Making Torch Cuts

4) Leaning back to rest and stretch between torch cuts (Figure 12)

Figure 13. Worker Moving Torch Leads to New Area

5) Moving torch lines to new location for next cut (Figure 13).

D2.2. Torch Cutting Ergonomic Risk Factors

During typical torch cutting on the deck, the worker assumes relatively constrained and static postures with flexed knees, hips and torso.

D2.3. Ergonomic Analysis of Workers in Torch Cutting Process

Using several of the exposure assessment tools outlined above, an ergonomic analysis was performed for the worker performing the torch cutting task. A RULA analysis was performed on five distinct subtasks within the torch cutting activity (D9.2 Table 6). According to this specific exposure assessment tool, the actual torch cutting subtask scored a 7 on a scale of 1 to 7 (investigate and change immediately). Three subtasks including adjusting body position and clearing debris, cleaning the cut with a wrench, and leaning back to rest resulted in scores of 3 and 4 (investigate further). The final subtask of moving torch leads to get into a new location was deemed “acceptable” with a score of two out of seven.

A Strain Index analysis was performed for the torch cutting activity (D9.2 Table 7) with the following results:

1) the Intensity of Exertion was rated as “Somewhat Hard” and given a multiplier score of 3.0 on a scale of 1 to 13
2) the Duration of the task was rated as greater than 80 percent of the task cycle, resulting in a multiplier of 3.0 on a scale of 0.5 to 3.0

3) The Efforts per Minute were considered to be nearly static exertions, and consequently is rated as a multiplier of 3.0 on a scale of 0.5 to 3.0

4) the Hand/Wrist posture was rated as “Fair,” resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0

5) the Speed of Work was rated as “Fair,” resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0

6) the Duration of Task per Day was rated to be between 2 and 4 hours, resulting in a multiplier of 0.75 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 30.4. An SI score between 5 and 30 is correlated to an incidence rate of about 77 distal upper extremity injuries per 100 FTE. Regardless of actual incidence rates, the Strain Index identifies this task as one which exposes the worker to an increased likelihood of upper extremity musculoskeletal disorders.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the torch cutting task (D9.2 Table 8), of the 21 possible responses, 13 were negative, five were positive, and one was answered both negatively and positively depending upon the situation observed and two were not directly measured. With this exposure assessment tool, negative responses (70 percent) are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the torch cutting task (D9.2 Table 9), “corrective measures in the near future” were suggested for only two of five specific sub-tasks, those scoring a 2 on a 4-point scale. These sub-tasks were actual torch cutting and cleaning out the cut with a wrench. Analysis of the other three subtasks resulted in a score of 1 out of 4, suggesting no corrective measures were necessary.

The PLIBEL checklist exposure assessment tool was applied to the torch cutting task (D9.2 Table 10) and resulted in reports of low percentages (25.0 - 33.3 percent) of risk factors present for the feet, knees and hips, and low back. Moderate percentages (42.3 - 50 percent) of risk factors were present for the upper extremities. Several environmental and organizational modifying factors are present as well that can be considered in future analysis.

D3. WATERJET BLASTING OF VESSEL IN DRYDOCK

Figure 14. Worker Using Waterjet to Remove Paint from Vessel

D3.1. Waterjet Blasting Process

When a vessel comes in for hull repair work, it may be placed in a dry-dock to lift the vessel out of the water. Instead of using an abrasive blasting agent within the dry-dock to remove paint, a high-pressure water cannon is used. This process eliminates the need to recover the abrasive agent. A worker enters the platform of a powered lift truck which has been moved beside the vessel in the dry-dock. The worker raises and positions the platform to be near the work area. The worker activates the waterjet and proceeds to remove paint from the work surface.

Figure 15. Worker Braced in Man-lift Cage from Waterjet Recoil

Occasionally the worker will stop to inspect the work area since the worker's vision is hindered by the spray from the waterjet.

Figure 16. Worker Inspecting Area Blasted by Waterjet

D3.2. Waterjet Blasting Ergonomic Risk Factors

The waterjet blasting unit operates at very high pressure. This results in a high amount of force leaving the unit, forcing the worker to use a great deal of effort to maintain control of the unit. Since postures are fairly static with high force, it is possible that workers operating the waterjet blasting unit may experience chronic upper extremity musculoskeletal injuries.

D3.3. Ergonomic Analysis of Workers in Waterjet Blasting Process

Using several of the exposure assessment tools outlined above, an ergonomic analysis was performed for the worker performing the waterjet blasting task. A RULA analysis was performed on four distinct subtasks within the waterjet blasting activity (D9.3 Table 11). According to this specific exposure assessment tool, performing the actual blasting task while standing unbraced on the personnel platform on the manlift scored a 7 on a scale of 1 to 7 (investigate and change immediately). Performing the same task while braced against the railings of the platform resulted in a score of 6 on a scale of 1 to 7 (investigate further and change soon). Two other subtasks including adjusting body position and inspecting the work surface resulted in scores of 3 out of 7 (investigate further).

A Strain Index analysis was performed for the waterjet blasting activity (D9.3 Table 12) with the following results:

1) the Intensity of Exertion was rated as “Hard” and given a multiplier score of 6.0 on a scale of 1 to 13
2) the Duration of the task was rated as greater than 80 percent of the task cycle, resulting in a multiplier of 3.0 on a scale of 0.5 to 3.0
3) The Efforts per Minute were considered to be nearly static exertions, and consequently is rated as a multiplier of 3.0 on a scale of 0.5 to 3.0
4) the Hand/Wrist posture was rated as “Fair,” resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0
5) the Speed of Work was rated as “Fair,” resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
6) the Duration of Task per Day was rated to be between 2 and 4 hours, resulting in a multiplier of 0.75 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 60.75. An SI score between 31 and 60 is correlated to an incidence rate of about 106 distal upper extremity injuries per 100 FTE. An SI score greater than 60 is correlated to an incidence rate of about 130 distal upper extremity injuries per 100 FTE. Regardless of actual incidence rates, the Strain Index identifies this task as one which exposes the worker to an increased likelihood of upper extremity musculoskeletal disorders.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the waterjet blasting task (D9.3 Table 13), of the 21 possible responses, ten were negative, eight were positive, and one was answered both negatively and positively depending upon the situation observed and two were not directly measured. With this exposure assessment tool, negative responses (52.5 percent) are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the waterjet blasting task (D9.3 Table 14), "corrective measures in the near future" were suggested for only one of the four specific sub-tasks, scoring a 2 on a 4-point scale. This sub-task was the worker repositioning themselves on the platform. Analysis of the other three subtasks resulted in a score of 1 out of 4, suggesting no corrective measures were necessary.

The PLIBEL checklist exposure assessment tool was applied to the waterjet blasting task (D9.3 Table 15) and resulted in reports of a high percentage (72.7 percent) of risk factors present for the elbows, forearms, and hands. Moderate percentages (37.5 - 50 percent) of risk factors were present for all other body parts. Several environmental and organizational modifying factors are present as well that can be considered in future analysis.

D4. GRINDING ONBOARD VESSEL

Figure 17. Shipfitter Grinding Deck Stiffeners

D4.1. Grinding Process

In any ship repair process, grinding is a primary task. Paint must be removed from bulkheads or decks prior to painting; weld beads must be ground flush with the plates or attachments. Grinding surfaces can be vertical or horizontal, at floor level, overhead or somewhere in between. The worker may be standing, kneeling, squatting or even laying down to perform the task.

Figure 18. Shipfitter Grinding Deck Stiffeners in Awkward Posture

Figure 19. Grinding Deck Stiffeners for Deck Replacement

Figure 20. Shipfitter Inspecting Grinding Results

D4.2. Grinding Ergonomic Risk Factors

The worker, whether a shipfitter, welder, or painter, often must assume awkward or constrained postures to get into position to grind. The grinder transmit vibration to the hand and arm of the worker. The work is primarily static which is generally very fatiguing for involved muscles.

D4.3. Ergonomic Analysis of Workers in Grinding Process

Using several of the exposure assessment tools outlined above, an ergonomic analysis was performed for the worker performing the grinding task while laying over an opening in the deck. A RULA analysis was performed on six distinct subtasks within the grinding activity (D9.4 Table 16). According to this specific exposure assessment tool, two subtasks, grinding and torch cutting, scored a 6 on a scale of 1 to 7 (investigate further and change soon). Three subtasks including adjusting the tool position, deslagging and resting or inspecting the work resulted in scores of 3 and 4 (investigate further). The final subtask of repositioning the worker's body to get into a new posture was deemed "acceptable" with a score of two out of seven.

A Strain Index analysis was performed for the grinding activity (D9.4 Table 17) with the following results:

1) the Intensity of Exertion was rated as "Hard" and given a multiplier score of 6.0 on a scale of 1 to 13

2) the Duration of the task was rated as being between 50 and 79 percent of the task cycle, resulting in a multiplier of 2.0 on a scale of 0.5 to 3.0

3) The Efforts per Minute were considered to be nearly static exertions, and consequently is rated as a multiplier of 3.0 on a scale of 0.5 to 3.0

4) the Hand/Wrist posture was rated as "Fair," resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0

5) the Speed of Work was rated as "Fair," resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0

6) the Duration of Task per Day was rated to be between 2 and 4 hours, resulting in a multiplier of 0.75 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 40.5. An SI score between 31 and 60 is correlated to an incidence rate of about 106 distal upper extremity injuries per 100 FTE. Regardless of actual incidence rates, the Strain Index identifies this task as one which exposes the worker to an increased likelihood of upper extremity musculoskeletal disorders.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the grinding task (D9.4 Table 18), of the 21 possible responses, 14 were negative, six were positive, and one was answered both negatively and positively depending upon the situation observed. With this exposure assessment tool, negative responses (68 percent) are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the grinding task (D9.4 Table 19), “corrective measures as soon as possible” were suggested for only two of six specific sub-tasks, those scoring a 3 on a 4-point scale. These sub-tasks were grinding and torch cutting. Three subtasks resulted in a score of 2 out of 4 or “corrective measures in near future.” These tasks were adjusting the tool position, deslagging and resting or inspecting the work. Analysis of the final subtasks, repositioning the worker's body, resulted in a score of 1 out of 4, suggesting no corrective measures were necessary.

The PLIBEL checklist exposure assessment tool was applied to the grinding task (D9.4 Table 20) and resulted in a relatively high percentage (72.7 percent) of risk factors present for the elbows, forearms and hands. Moderate percentages (37.5 - 50 percent) of risk factors were present for all other body parts. Several environmental and organizational modifying factors are present as well that can be considered in future analysis.

D5. WELDING ONBOARD VESSEL

D5.1. Welding Process

There are three primary types of welding that occur during ship repair processes: manual stick welding, manual wire welding and semi-automatic wire welding. Stick welding has already been addressed previously for pipe welding. Semi-automatic welding is performed primarily for long straight welds on horizontal surfaces, such as decks. This type of welding is often flux core arc welding where the wire is continuously fed to the arc and the electrode wire has a flux core center that helps to shield the weld. The machine is positioned on the seam to be welded, activated and then guided by the operator.

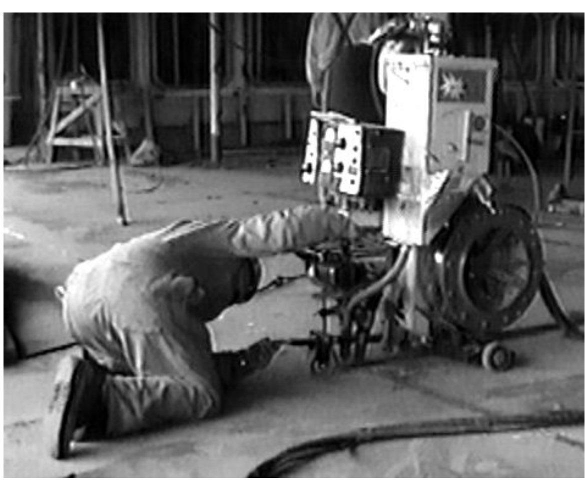

Figure 21. Worker Setting Up Semi-Automatic Wire-Feed Welder

Figure 22. Worker Operating Semi-Automatic Wire-Feed Welder

Figure 23. Wire Welding While Standing

Figure 24. Wire Welding While Kneeling

Figure 25. Worker Deslagging Wire Weld

Wire welding is performed for the majority of welding tasks. The wire electrode is again continuously fed to the arc and may or may not be shielded by a flux core.

D5.2. Welding Ergonomic Risk Factors

During semi-automatic welding on deck plates, the worker must kneel or squat low to align and operate the automatic welding unit. These postures may result in strain to the legs and lower back. For wire welding, the worker may assume a variety of postures, often constrained, to perform the welding task. Often, the work is static, resulting in muscle fatigue of the arms.

D5.3. Ergonomic Analysis of Workers in Welding Process

A RULA analysis was performed on two distinct subtasks within the automatic welding activity (D9.5 Table 21). According to this specific exposure assessment tool, the preparation and alignment subtask scored a 7 on a scale of 1 to 7 (investigate and change immediately) due primarily to kneeling low to the ground to align the arc. The other subtask of guiding the automatic welding unit rated a score of five out of seven or "investigate further and change soon" again due primarily to the posture the worker assumes while performing the task.

Using several of the exposure assessment tools outlined above, an ergonomic analysis was performed for the worker performing the wire welding task. A RULA analysis was performed on six distinct subtasks within the wire welding activity (D9.5 Table 22). According to this specific exposure assessment tool, the actual wire welding subtask while standing scored a 7 on a scale of 1 to 7 (investigate and change immediately). Wire welding while kneeling scored a 6 out of 7, "investigate further and change soon." The four other subtasks, such as deslagging and inspecting the work, resulted in scores of 3 and 4 (investigate further).

A Strain Index analysis was performed for the wire welding activity (D9.5 Table 23) with the following results:

1) the Intensity of Exertion was rated as “Somewhat Hard” and given a multiplier score of 3.0 on a scale of 1 to 13
2) the Duration of the task was rated as being between 30 and 49 percent of the task cycle, resulting in a multiplier of 1.5 on a scale of 0.5 to 3.0
3) the Efforts per Minute were measured to be low but also considered to be nearly static exertions, and consequently a compromise rating of a multiplier of 1.5 on a scale of 0.5 to 3.0 was given
4) the Hand/Wrist posture was rated as “Fair,” resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0
5) the Speed of Work was rated as “Fair,” resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
6) the Duration of Task per Day was rated to be between 2 and 4 hours, resulting in a multiplier of 0.75 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 7.6 An SI score between 5 and 30 is correlated to an incidence rate of about 77 distal upper extremity injuries per 100 FTE. Regardless of actual incidence rates, the Strain Index identifies this task as one which exposes the worker to an increased likelihood of upper extremity musculoskeletal disorders.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the wire welding task (D9.5 Table 24), of the 21 possible responses, 12 were negative, eight were positive, and one was answered both negatively and positively depending upon the situation observed. With this exposure assessment tool, negative responses (60 percent) are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the wire welding task (D9.5 Table 25), "corrective measures in the near future" were suggested for five of the six specific sub-tasks, those scoring a 2 on a 4-point scale. These sub-tasks included welding while standing, deslagging and inspecting the work. Analysis of the other subtask resulted in a score of 1 out of 4, suggesting no corrective measures were necessary.

The PLIBEL checklist exposure assessment tool was applied to the wire welding task (D9.5 Table 26) and resulted in reports of moderate percentages (37.5 - 45.5 percent) of risk factors being present for the all body parts. Several environmental and organizational modifying factors are present as well that can be considered in future analysis.

D6. CONTROL TECHNOLOGY

Possible interventions and control technologies are mentioned briefly here. A more detailed report of possible interventions is under development. Five work processes within a ship repair facility were surveyed to determine the presence of risk factors associated with musculoskeletal disorders. The pipe welding task requires workers to combine pipe assemblies, usually in place onboard the vessel. These conditions can result in constrained and awkward postures and unstable footing. Similar conditions also occur for torch cutting, grinding and other welding tasks. Since each repair process to be carried out onboard a vessel is constrained by the physical layout and dimensions of the existing structure, very little can be done in the area of work station redesign or even engineering interventions, in general. It is, however, possible to address concerns raised by improper tool selection and tool usage and poor body positioning. It is suggested that basic ergonomics awareness training be considered for all production workers, emphasizing the areas cited above. While direct changes to the work environment are minimized due to the constraints of ship repair, it is possible to educate the workforce on proper procedures, better work methods and postures to assume while performing the work onboard vessels.

Whenever a worker has to kneel or squat for long periods of time to conduct their work, whether it be torch cutting, grinding or welding, it is suggested that adequate stools or benches be provided which allow the worker to sit to lessen the stress on the knees while still enabling the worker to perform the assigned task at or near floor level without additional strain on the lower back.

Figure 26. Worker Running Automatic Welder While on Stool

Figure 27. Closeup of Worker Stool

The primary concern with the waterjet blasting is the worker having to hold the water cannon in their hands to control and direct the high-pressure water spray. It is suggested that an orbital nozzle mount, similar to those found on fire engines, be fixed to the railing of the platform of the lift.   The water spray can still be directed to the hull or other work surface with a high degree of flexibility, but yet the nozzle mount removes the worker from the strain of holding the water cannon directly.

D7. CONCLUSIONS AND RECOMMENDATIONS

Five distinct repair processes were examined to quantify the musculoskeletal risk factors associated with these processes. The processes included: pipe welding, torch cutting, waterjet blasting, grinding, and welding. Since ship repair work greatly differs from ship construction processes, particularly with respect to the ability to change the work environment, it is suggested that administrative controls such as ergonomics awareness training may be suitable interventions for the ship repair workforce, rather than direct changes to the work station or processes themselves..

It is recommended that further action be taken to mitigate the exposure to musculoskeletal risk factors within each of the identified tasks. The implementation of ergonomic interventions has been found to reduce the amount and severity of musculoskeletal disorders within the working population in various industries. It is recommended that ergonomic interventions, both engineering and administrative, be implemented to minimize hazards in the identified job tasks.

D8. REFERENCES

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D9. ERGONOMIC ANALYSIS TABLES

D9.1. Pipe Welders

Table 1. Pipe Welders RULA

Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

Date/ Time 4/13/00 Facility: Area/ Shop: Onboard vessel
Task : Pipe welding task Performed by

RULA: Posture Sampling Results

RULA Component	**Frame # 92040 Arctime**		**Frame # 101880 Deslag**		**Frame # 98940 Change, bend stick**		**Frame # 120539 Position body**		**Frame # 107760 Change tools**		**Frame # 108180 Grind w/ angle grinder**	
	Spec	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*
Shoulder Extension/ Flexion	sl flex	2	mod flex	3	neut	1	neut	1	neut	1	sl flex	2
Shoulder is Raised (+1)		1		1		0		0		0		0
Upper Arm Abducted (+1)		0		0		0		0		0		0
Arm supported, leaning (-1)		0		0		0		0		0		0
Elbow Extension/ Flexion	flx	2	neut	2	neut	2	neut	2	neut	2	neut	2
Shoulder Abduction/ Adduction	neut	0	neut	0	neut	0	neut	0	neut	0	add	1
Shoulder Lateral/ Medial	neut	0	neut	0	neut	0	neut	0	neut	0	mod med	1
Wrist Extension/ Flexion	neut	1	ext	2	neut	1	neut	1	neut	1	ext	2
Wrist Deviation	ulnar	1	ulnar	1	neut	0	neut	0	neut	0	ulnar	1
Wrist Bent from Midline (+1)		0		0		0		0		0		0
Wrist Twist (1) In mid range or (2) End of range		1		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		0		0		1
Arm and Wrist Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		1		0		0		1		2

Table 1. Pipe Welders RULA (continued)

RULA Component	**Frame # 92040 Arctime**		**Frame # 101880 Deslag**		**Frame # 98940 Change, bend stick**		**Frame # 120539 Position body**		**Frame # 107760 Change tools**		**Frame # 108180 Grind w/ angle grinder**	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Neck Extension/ Flexion	sl flx	2	ext	4	extr flx	3	ext	***4***	extr flx	3	sl flx	2
Neck Twist (+1)		0		1		0		0		0		0
Neck Side-Bent (+1)		0		0		0		0		0		0
Trunk Extension/ Flexion	neut	1	ext	1	neut	1	neut	1	sl flx	2	neut	1
Trunk Twist (+1)		0		0		0		0		0		0
Trunk Side Bend (+1)		0		0		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		0		0		0		1
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		2		1		0		1		2
Total RULA Score	**6**		**6**		**3**		**2**		**3**		**6**	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 2. Pipe Welders Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
Moore and Garg, 1995

Date/ Time 4/13/00 Facility: Area/ Shop: Onboard vessel
Task : Pipe welding task Performed by:

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.					
Rating Criterion	**% MS** *(percentage of maximal strength)*	**Borg Scale** *(Compare to Borg Cr-10 Scale)*	**Perceived Effort**	**Rating**	**Multiplier**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**3.0**

Table 2. Pipe Welders Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: % Duration of Exertion = 100 x duration of all exertions (sec) / Total observation time (sec) = 100 x 1310 (sec)/ 1677 (sec) = 78	**Rating Criterion**	**Rating**	**Multiplier**
	< 10	1	0.5
	10 - 29	2	1.0
	30 - 49	3	1.5
	50 -79	4	2.0
	> or = 80	5	3.0
Duration of Exertion Multiplier			**2.0**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: Efforts per Minute = number of exertions / total observation time (min) = 61/ 28 = 2.2	**Rating Criterion**	**Rating**	**Multiplier**
	< 4	1	0.5
	4 - 8	2	1.0
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			**0.5**

Table 2. Pipe Welders Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	**Wrist Extension** *(Stetson et al, 1991)*	**Wrist Flexion** *(Stetson et al, 1991)*	**Ulnar Deviation** *(Stetson et al, 1991)*	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral (*estimated, based on RULAs performed)	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.5**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	**Compared to MTM** *(observed pace is divided by MTM's predicted pace and expressed as %)*	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	91 -100%	"normal" speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 2. Pipe Welders Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
Duration of Task per Day (hrs)	< or = 1 hrs	1	0.25
= duration of task (hrs) + duration of task (hrs) + ...	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
= (estimate @ 2-4 hrs)	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**0.75**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**	**=**	**SI SCORE**
3.0 X	**2.0 X**	**0.5 X**	**1.5 X**	**1.0 X**	**0.75**		**3.4**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 3. Pipe Welders UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
Lifshitz and Armstrong (1986)

Date/ Time: 4/13/00 Facility:
Task: Pipe Welding Area/ Shop: Onboard Vessel

* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	No	Yes
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?	N	Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		

5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	N	
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	N	Y (grinder)
6.3 Is the handle of the tool made from material other than metal?		Y
6.4 Is the weight of the tool below 4 kg (9lbs)?		Y
6.5 Is the tool suspended?	N	
TOTAL	**16 (67%)**	**8 (33%)**

Table 4. Pipe Welders OWAS

OWAS: OVAKO Work Analysis System
Louhevaara and Suurnäkki (1992)

Procedure: Observe workers at intervals of 30-60 seconds. Record postures and forces over a representative period (~ 45 minutes)

Date/ Time 4/13/00
Task Pipe Welder (stick)

Facility
Area/ Shop Onboard Vessel

Risk Factor	**Work Phase 1** **Position stick holder**	**Work Phase 2** **Arctime**	**Work Phase 3** **Deslag**	**Work Phase 4** **Change, bend stick**	**Work Phase 5** **Position body**	**Work Phase 6** **Change tools**	**Work Phase 7** **Grind O/H w/ electric offset**	**Work Phase 8** **Resting, change over to wire**
TOTAL Combination Posture Score	**1**	**1**	**2**	**1**	**1**	**2**	**1**	**1**
Common Posture Combinations (collapsed across work phases)								
Back	1	1	2	1	1			
Arms	2	1	2	1	3			
Legs	3	7	2	2	2			
Posture Repetition (% of working time)	14	27	18	13	15			
Back % of Working Time Score	1	1	1	1	1			
Arms % of Working Time Score	1	1	1	1	1			
Legs % of Working Time Score	1	1	1	1	1			

ACTION CATEGORIES:
1 = No corrective measures
2 = Corrective measures in near future
3 = Corrective measures as soon as possible
4 = Corrective measures immediately

Table 4. Pipe Welders OWAS (continued)

Risk Factor	**Work Phase 1** **Position stick**	**Work Phase 2** **Arctime**	**Work Phase 3** **Deslag**	**Work Phase 4** **Change, bend**	**Work Phase 5** **Position body**	**Work Phase 6** **Change tools**	**Work Phase 7** **Grind O/H w/**	**Work Phase 8** **Resting, change**

	holder			stick			electric offset	over to wire
Posture								
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	1	1	2	1	1	2	1	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	2	2	2	1	1	1	3	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	3	2, 3	2	2	7	7	2	7
Load/ Use of Force								
1 = weight or force needed is = or <10 kg (<22lbs)	1	1	1	1	1	1	2	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)								
3 = weight or force > 20 kg (>44 lbs)								
Phase Repetition								
% of working time (0,10,20,30,40,50,60,70,80,90,100)	2	12	18	13	12	5	15	15

Table 5. Pipe Welders PLIBEL

PLIBEL Checklist, Kemmlert (1995)

Date/ Time 4/13/00 | Facility
Task Pipe Welder (stick) | Area/ Shop Onboard Vessel

Section I: Musculoskeletal Risk Factors
Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			N	N	N
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	N				N
6: If work performed standing, is there no possibility to sit and rest?			Y	Y	Y
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			Y	Y	Y
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			Y	Y	Y
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	N				N
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 5. Pipe Welders PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	N				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	Y				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	N				N
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	Y				Y
f) handling below knee length	N				N
g) handling above shoulder height	Y				Y
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	N	N			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	N	N			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		N			
c) uncomfortable hand positions?		Y			

d) switches or keyboards?		N			

Table 5. Pipe Welders PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	9	5	4	4	8
PERCENTAGE	34.6	45.5	50.0	50.0	38.1

Section II: Environmental / Organizational Risk Factors (Modifying) **Answer below questions, use to modify interpretation of musculoskeletal scores**	
18: Is there no possibility to take breaks and pauses?	N
19: Is there no possibility to choose order and type of work tasks or pace of work?	N
20: Is the job performed under time demands or psychological stress?	N
21:Can the work have unusual or expected situations?	N
22: Are the following present?	
a) cold	Y
b) heat	Y
c) draft	Y
d) noise	Y
e) troublesome visual conditions	Y
f) jerks, shakes, or vibration	N

Environmental / Organizational Risk Factors Score	
SUM	5
PERCENTAGE	50.0

D9.2. Torch Cutters

Table 6. Torch Cutters RULA

Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

Day/Time: 4/13/00 Facility:
Task: Torch Cutting Area/Shop: Onboard Vessel

RULA: Posture Sampling Results

RULA Component	**Frame # 77580 Apply torch to surface (torch- time)**		**Frame # 51450 Adjust body position, clear debris**		**Frame # 60450 Begin new cut (move location)**		**Frame # 65460 Rest**		**Frame # 65850 Cleaning cut with wrench**	
	Specific	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*
Shoulder Extension/ Flexion	sl flex	2	neut	1	neut	1	neut	1	mod flex	3
Shoulder is Raised (+1)		0		0		0		0		0
Upper Arm Abducted (+1)		0		0		0		0		0
Arm supported, leaning (-1)		0		0		0		0		0
Elbow Extension/ Flexion	neut	2	neut	2	ext	1	ext	1	ext	1
Shoulder Abduction/ Adduction	neut	0	neut	0	neut	0	neut	0	neut	0
Shoulder Lateral/ Medial	mod med	1	neut	0	neut	0	neut	0	lat	1
Wrist Extension/ Flexion	flx	2	neut	1	neut	1	neut	1	neut	1
Wrist Deviation	ulnar	1	neut	0	neut	0	neut	0	neut	0
Wrist Bent from Midline (+1)		0		0		0		0		0
Wrist Twist (1) In mid range Or (2) End of range		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		0		0
Arm and Wrist Force/ load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		1		1		1		0

Table 6. Torch Cutters RULA (continued)

RULA Component	Frame # 77580 Apply torch to surface (torch-time)		Frame # 51450 Adjust body position, clear debris		Frame # 60450 Begin new cut (move location)		Frame # 65460 Rest		Frame # 65850 Cleaning cut with wrench	
	Specific	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*
Neck Extension/ Flexion		2		3		1		1		2
Neck Twist (+1)		0		0		0		0		0
Neck Side-Bent (+1)		0		0		0		0		0
Trunk Extension/ Flexion	flx	3	neut	1	neut	1	neut	1	flx	3
Trunk Twist (+1)		0		0		0		0		0
Trunk Side Bend (+1)		0		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		1		1
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		1		1		2		2
Total RULA Score	**7**		**3**		**2**		**3**		**4**	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 7. Torch Cutters Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
Moore and Garg, 1995

Date/ Time 4/13/00________ Facility:
Task : Torch Cutting Task___ Area/ Shop: Onboard vessel

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.					
Rating Criterion	**% MS** *(percentage of maximal strength)*	**Borg Scale** *(Compare to Borg Cr-10 Scale)*	**Perceived Effort**	**Rating**	**Multiplier**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**3.0**

Table 7. Torch Cutters Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
% Duration of Exertion	< 10	1	0.5
= 100 x duration of all exertions (sec) / Total observation time (sec)	10 - 29	2	1.0
	30 - 49	3	1.5
= 100 x 1430 (sec)/ 1549 (sec) = 92	50 -79	4	2.0
	> or = 80	5	3.0
Duration of Exertion Multiplier			**3.0**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
Efforts per Minute	< 4	1	0.5
= number of exertions / total observation time (min)	4 - 8	2	1.0
	9 -14	3	1.5
= nearly static exertion, therefore	15 -19	4	2.0
= 3.0	> or = 20	5	3.0
Efforts per Minute Multiplier			**3.0**

Table 7. Torch Cutters Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	**Wrist Extension** *(Stetson et al, 1991)*	**Wrist Flexion** *(Stetson et al, 1991)*	**Ulnar Deviation** *(Stetson et al, 1991)*	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral (*estimated, based on RULAs performed)	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.5**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	**Compared to MTM** *(observed pace is divided by MTM's predicted pace and expressed as %)*	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	91 -100%	"normal" speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 7. Torch Cutters Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
Duration of Task per Day (hrs)	< or = 1 hrs	1	0.25
= duration of task (hrs) + duration of task (hrs) + ...	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
= (estimate @ 2-4 hrs)	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**0.75**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**		**SI SCORE**
3.0 X	**3.0 X**	**3.0 X**	**1.5 X**	**1.0 X**	**0.75**	**=**	**30.4**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 8. Torch Cutters UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
Lifshitz and Armstrong (1986)

Date/ Time: 4/13/00 Facility:
Task: Torch Cutting Area/ Shop: Onboard Vessel
* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	No	Yes
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?		Y
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		

5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	N	
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	Not measured	
6.3 Is the handle of the tool made from material other than metal?	N	
6.4 Is the weight of the tool below 4 kg (9lbs)?	Not measured	
6.5 Is the tool suspended?	N	
TOTAL	**14 (70%)**	**6 (30%)**

Table 9. Torch Cutters OWAS

OWAS: OVAKO Work Analysis System
Louhevaara and Suurnäkki (1992)

Procedure: Observe workers at intervals of 30-60 seconds. Record postures and forces over a representative period (~ 45 minutes)

Date/ Time: 4/13/00 Facility: _____
Task Pipe Welder (stick) Area/ Shop Onboard Vessel

Risk Factor	**Work Phase 1** **Apply torch to surface (torch time)**	**Work Phase 2** **Adjust body position, clear debris**	**Work Phase 3** **Begin new cut (move location)**	**Work Phase 4** **Rest**	**Work Phase 5** **Cleaning cut with wrench**
TOTAL Combination Posture Score	**2**	**1**	**1**	**1**	**2**
Common Posture Combinations (collapsed across work phases)					
Back	2	1	1		
Arms	1	1	1		
Legs	6	6	7		
Posture Repetition (% of working time)	81	15	3		
Back % of Working Time Score	3	1	1		
Arms % of Working Time Score	1	1	1		
Legs % of Working Time Score	3	1	1		
ACTION CATEGORIES: 1 = no corrective measures 2 = corrective measures in the near future 3 = corrective measures as soon as possible 4 = corrective measures immediately					

Risk Factor	**Work Phase 1** **Apply torch to surface (torch time)**	**Work Phase 2** **Adjust body position, clear debris**	**Work Phase 3** **Begin new cut (move location)**	**Work Phase 4** **Rest**	**Work Phase 5** **Cleaning cut with wrench**
Posture					
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2	1	1	1	2

Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	6	6	7	6	6
Load/ Use of Force					
1 = weight or force needed is = or <10 kg (<22lbs)	1	1	1	1	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)					
3 = weight or force > 20 kg (>44 lbs)					
Phase Repetition					
% of working time (0,10,20,30,40,50,60,70,80,90,100)	79	9	3	6	2

Table 10. Torch Cutters PLIBEL
PLIBEL Checklist, Kemmlert (1995)

Date/ Time: 4/13/00 | Facility: _____
Task: Torch Cutter | Area/ Shop: Onboard Vessel

Section I: Musculoskeletal Risk Factors
Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			N	N	N
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	N				N
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			Y	Y	Y
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 10. Torch Cutters PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	N				N
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	Y				Y
f) handling below knee length	N				N
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	N	N			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		N			
c) uncomfortable hand positions?		Y			

d) switches or keyboards?		N			

Table 10. Torch Cutters PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	11	6	2	2	7
PERCENTAGE	42.3	54.5	25.0	25.0	33.3

Section II: Environmental / Organizational Risk Factors (Modifying) **Answer below questions, use to modify interpretation of musculoskeletal scores**	
18: Is there no possibility to take breaks and pauses?	N
19: Is there no possibility to choose order and type of work tasks or pace of work?	N
20: Is the job performed under time demands or psychological stress?	N
21:Can the work have unusual or expected situations?	N
22: Are the following present?	
a) cold	Y
b) heat	Y
c) draft	Y
d) noise	Y
e) troublesome visual conditions	Y
f) jerks, shakes, or vibration	N

Environmental / Organizational Risk Factors Score	
SUM	5
PERCENTAGE	50.0

D9.3. Waterjet Blaster

Table 11. Waterjet Blaster RULA

Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

Day/Time: 4/13/00 | Facility:
Task: Waterjet Blasting | Area/Shop: Vessel in Drydock

RULA: Posture Sampling Results

RULA Component	Frame # 101460 Waterblasting/ standing		Frame # 103110 Waterblasting/ standing braced		Frame # 101880 Inspect		Frame # 105120 Reposition	
	Specific	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*
Shoulder Extension/ Flexion	mod flex	3	mod flex	3	neut	1	sl flex	2
Shoulder is Raised (+1)		0		0		0		0
Upper Arm Abducted (+1)		0		0		0		0
Arm supported, leaning (-1)		0		0		0		0
Elbow Extension/ Flexion	ext	1	ext	1	neut	2	ext	1
Shoulder Abduction/ Adduction	neut	0	neut	0	neut	0	neut	0
Shoulder Lateral/ Medial	mod med	1	mod med	1	neut	0	neut	0
Wrist Extension/ Flexion	ext	2	ext	2	neut	1	neut	1
Wrist Deviation	neut	0	neut	0	neut	0	neut	0
Wrist Bent from Midline (+1)		0		0		0		0
Wrist Twist (1) In mid range Or (2) End of range		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		0		0
Arm and Wrist Force/ load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		3		3		1		1

Table 11. Waterjet Blaster RULA (continued)

RULA Component	**Frame # 101460** **Waterblasting/ standing**		**Frame # 103110** **Waterblasting/ standing braced**		**Frame # 101880** **Inspect**		**Frame # 105120** **Reposition**	
	Specific	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*
Neck Extension/ Flexion	sl flx	2	neut	1	neut	1	neut	1
Neck Twist (+1)		0		0		0		0
Neck Side-Bent (+1)		0		0		0		0
Trunk Extension/ Flexion	sl flx	2	neut	1	neut	1	mod flx	3
Trunk Twist (+1)		0		0		0		0
Trunk Side Bend (+1)		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		2		2		1
Total RULA Score	**7**		**6**		**3**		**3**	
1 or 2 = Acceptable 3 or 4 = Investigate Further 5 or 6 = Investigate Further and Change Soon 7 = Investigate and Change Immediately								

Table 12. Waterjet Blaster Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
Moore and Garg, 1995

Date/ Time 4/13/00
Task : Waterjet Blasting

Facility:
Area/ Shop: Vessel in Drydock

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.					
Rating Criterion	**% MS** *(percentage of maximal strength)*	**Borg Scale** *(Compare to Borg Cr-10 Scale)*	**Perceived Effort**	**Rating**	**Multiplier**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**6.0**

Table 12. Waterjet Blaster Strain Index (continued)

<table>
<tr><td colspan="4">2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0</td></tr>
<tr><td rowspan="6">Worksheet:

% Duration of Exertion

= 100 x <u>duration of all exertions (sec)</u>
Total observation time (sec)

= 100 x 134 (sec)/ 145 (sec)
= 92</td><td>Rating Criterion</td><td>Rating</td><td>Multiplier</td></tr>
<tr><td>< 10</td><td>1</td><td>0.5</td></tr>
<tr><td>10 - 29</td><td>2</td><td>1.0</td></tr>
<tr><td>30 - 49</td><td>3</td><td>1.5</td></tr>
<tr><td>50 -79</td><td>4</td><td>2.0</td></tr>
<tr><td>> or = 80</td><td>5</td><td>3.0</td></tr>
<tr><td colspan="3">Duration of Exertion Multiplier</td><td>3.0</td></tr>
</table>

<table>
<tr><td colspan="4">3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0</td></tr>
<tr><td rowspan="6">Worksheet:

Efforts per Minute

= <u>number of exertions</u>
total observation time (min)

= nearly static exertion, therefore

= 3.0</td><td>Rating Criterion</td><td>Rating</td><td>Multiplier</td></tr>
<tr><td>< 4</td><td>1</td><td>0.5</td></tr>
<tr><td>4 - 8</td><td>2</td><td>1.0</td></tr>
<tr><td>9 -14</td><td>3</td><td>1.5</td></tr>
<tr><td>15 -19</td><td>4</td><td>2.0</td></tr>
<tr><td>> or = 20</td><td>5</td><td>3.0</td></tr>
<tr><td colspan="3">Efforts per Minute Multiplier</td><td>3.0</td></tr>
</table>

Table 12. Waterjet Blaster Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	**Wrist Extension** *(Stetson et al, 1991)*	**Wrist Flexion** *(Stetson et al, 1991)*	**Ulnar Deviation** *(Stetson et al, 1991)*	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral (*estimated, based on RULAs performed)	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.5**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	**Compared to MTM** *(observed pace is divided by MTM's predicted pace and expressed as %)*	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	91 -100%	"normal" speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 12. Waterjet Blaster Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
Duration of Task per Day (hrs)	< or = 1 hrs	1	0.25
= duration of task (hrs) + duration of task (hrs) + ...	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
= (estimate @ 2-4 hrs)	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**0.75**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**		**SI SCORE**
6.0 X	**3.0 X**	**3.0 X**	**1.5 X**	**1.0 X**	**0.75**	**=**	**60.75**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 13. Waterjet Blaster UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
Lifshitz and Armstrong (1986)

Date/ Time: 4/13/00 Facility:
Task: Waterjet Blasting Area/ Shop: Vessel in Drydock
* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	No	Yes
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?	N	
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?		Y
3.4 Can the tool be used without deviating the wrist from side to side?		Y
3.5 Can the worker be seated while performing the job?		Y
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?		Y
4.2 Can the height of the work surface be adjusted?		Y
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	Not measured	
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	Not measured	
6.3 Is the handle of the tool made from material other than metal?	N	
6.4 Is the weight of the tool below 4 kg (9lbs)?	N	
6.5 Is the tool suspended?	N	
TOTAL	**11 (55%)**	**9 (45%)**

Table 14. Waterjet Blaster OWAS

OWAS: OVAKO Work Analysis System
Louhevaara and Suurnäkki (1992)

Procedure: Observe workers at intervals of 30-60 seconds. Record postures and forces over a representative period (~ 45 minutes)

Date/ Time: 4/13/00
Task: Waterjet Blasting

Facility: ______
Area/Shop: Vessel in Drydock

Risk Factor	**Work Phase 1** **Waterblasting /standing**	**Work Phase 2** **Waterblasting/ standing braced**	**Work Phase 3** **Inspect**	**Work Phase 4** **Reposition**
TOTAL Combination Posture Score	**1**	**1**	**1**	**2**
Common Posture Combinations (collapsed across work phases)				
Back	1	1	2	
Arms	3	1	2	
Legs	3	2	2	
Posture Repetition (% of working time)	73	8	18	
BACK % of Working Time SCORE	1	1	1	
ARMS % of Working Time SCORE	3	1	1	
LEGS % of Working Time SCORE	2	1	1	

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Table 14. Waterjet Blaster OWAS (continued)

Risk Factor	**Work Phase 1** **Waterblasting standing**	**Work Phase 2** **Waterblasting/ standing braced**	**Work Phase 3** **Inspect**	**Work Phase 4** **Reposition**
Posture				
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	1	1	1	2
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	3	3	1	2
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	3	3	2	2
Load/ Use of Force				
1 = weight or force needed is = or <10 kg (<22lbs) 2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs) 3 = weight or force > 20 kg (>44 lbs)	3	3	1	1
Phase Repetition				
% of working time (0,10,20,30,40,50,60,70,80,90,100)	16	57	8	20

Table 15. Waterjet Blaster PLIBEL

PLIBEL Checklist, Kemmlert (1995)

Date/ Time: 4/13/00 Facility: _____
Task: Waterjet Blasting Area/ Shop: Vessel in Drydock

Section I: Musculoskeletal Risk Factors
Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			Y	Y	Y
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	N				N
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 15. Waterjet Blaster PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	N				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	Y				Y
e) handling beyond forearm length	Y				Y
f) handling below knee length	N				N
g) handling above shoulder height	Y				Y
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			

d) switches or keyboards?		N			

Table 15. Waterjet Blaster PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	13	8	3	3	10
PERCENTAGE	50.0	72.7	37.5	37.5	47.6

Section II: Environmental / Organizational Risk Factors (Modifying) **Answer below questions, use to modify interpretation of musculoskeletal scores**	
18: Is there no possibility to take breaks and pauses?	N
19: Is there no possibility to choose order and type of work tasks or pace of work?	Y
20: Is the job performed under time demands or psychological stress?	N
21:Can the work have unusual or expected situations?	N
22: Are the following present?	
a) cold	Y
b) heat	Y
c) draft	Y
d) noise	Y
e) troublesome visual conditions	N
f) jerks, shakes, or vibration	Y
Environmental / Organizational Risk Factors Score	
SUM	6
PERCENTAGE	60.0

D9.4. Shipfitter Grinding

Table 16. Shipfitter Grinding RULA

Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

Day/Time: 4/13/00 — Facility:
Task: Shipfitter Grinding — Area/Shop: Onboard Vessel

RULA: Posture Sampling Results

RULA Component	Frame # 57300, 57930 Grind surface		Frame # 59250 Reposition body		Frame # 60990 Reposition adjust tool		Frame # 66090 Inspect, rest		Frame # 82230 Torch cut		Frame # 91680 De-slag	
	Specific	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*
Shoulder Extension/ Flexion	sl flex	2	sl flex	2	mod flex	3	sl flex	2	mod flex	3	mod flex	3
Shoulder is Raised (+1)		1		0		1		1		1		0
Upper Arm Abducted (+1)		0		0		0		0		1		0
Arm supported, leaning (-1)		-1		-1		-1		-1		-1		0
Elbow Extension/ Flexion	ext	1	ext	1	ext	1	ext	1	neut	2	neut	2
Shoulder Abduction/ Adduction	add	1	neut	0	neut	0	neut	0	mod abd	1	neut	0
Shoulder Lateral/ Medial	neut	0	neut	0	neut	0	neut	0	lat	1	lat	1
Wrist Extension/ Flexion	ext	2	neut	1	neut	1	neut	1	ext	2	flx	2
Wrist Deviation	ulnar	1	neut	0	neut	0	neut	0	ulnar	1	neut	0
Wrist Bent from Midline (+1)		0		0		0		0		0		0
Wrist Twist (1) In mid range Or (2) End of range		1		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		0		1		0
Arm and Wrist Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		1		1		1		2		1

Table 16. Shipfitter Grinding RULA (continued)

RULA Component	Frame # 57300, 57930 Grind surface		Frame # 59250 Reposition body		Frame # 60990 Reposition adjust tool		Frame # 66090 Inspect, rest		Frame # 82230 Torch cut		Frame # 91680 De-slag	
	Specific	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*
Neck Extension/ Flexion		4		1		4		4		4		2
Neck Twist (+1)		0		0		0		0		0		0
Neck Side-Bent (+1)		0		0		0		0		0		0
Trunk Extension/ Flexion	neut	1	neut	1	neut	1	neut	1	neut	1	sl flx	2
Trunk Twist (+1)		0		0		0		0		0		0
Trunk Side Bend (+1)		0		0		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		0		1		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		1		1		1		1		1
Total RULA Score	**6**		**2**		**3**		**3**		**6**		**4**	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 17. Shipfitter Grinding Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
Moore and Garg, 1995

Date/ Time 4/13/00 Facility:
Task : Shipfitter Grinding Area/ Shop: Onboard Vessel

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.					
Rating Criterion	**% MS** *(percentage of maximal strength)*	**Borg Scale** ***(Compare to Borg Cr-10 Scale)***	**Perceived Effort**	**Rating**	**Multiplier**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**6.0**

Table 17. Shipfitter Grinding Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
% Duration of Exertion	< 10	1	0.5
= 100 x duration of all exertions (sec) / Total observation time (sec)	10 - 29	2	1.0
	30 - 49	3	1.5
= 100 x 1167 (sec)/ 1499 (sec) = 78	50 -79	4	2.0
	> or = 80	5	3.0
Duration of Exertion Multiplier			**2.0**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
Efforts per Minute	< 4	1	0.5
= number of exertions / total observation time (min)	4 - 8	2	1.0
	9 -14	3	1.5
= nearly static exertion, therefore	15 -19	4	2.0
= 3.0	> or = 20	5	3.0
Efforts per Minute Multiplier			**3.0**

Table 17. Shipfitter Grinding Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	**Wrist Extension** *(Stetson et al, 1991)*	**Wrist Flexion** *(Stetson et al, 1991)*	**Ulnar Deviation** *(Stetson et al, 1991)*	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral (*estimated, based on RULAs performed)	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.5**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	**Compared to MTM** *(observed pace is divided by MTM's predicted pace and expressed as %)*	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	91 -100%	"normal" speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 17. Shipfitter Grinding Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
Duration of Task per Day (hrs)	< or = 1 hrs	1	0.25
= duration of task (hrs) + duration of task (hrs) + ...	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
= (estimate @ 2-4 hrs)	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**0.75**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**	**=**	**SI SCORE**
6.0 X	**2.0 X**	**3.0 X**	**1.5 X**	**1.0 X**	**0.75**		**40.5**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 18. Shipfitter Grinding UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
Lifshitz and Armstrong (1986)

Date/ Time: 4/13/00 Facility:
Task: Shipfitter Grinding Area/ Shop: Onboard Vessel
* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	No	Yes
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?	N	
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?		Y
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	N (elec. grind.)	
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	N (elec. grind.)	
6.3 Is the handle of the tool made from material other than metal?		Y
6.4 Is the weight of the tool below 4 kg (9lbs)?		Y
6.5 Is the tool suspended?	N	
TOTAL	**15 (68.1%)**	**7 (31.8%)**

Table 19. Shipfitter Grinding OWAS

OWAS: OVAKO Work Analysis System
Louhevaara and Suurnäkki (1992)

Procedure: Observe workers at intervals of 30-60 seconds. Record postures and forces over a representative period (~ 45 minutes)

Date/ Time: 4/13/00 Facility: _____
Task: Shipfitter Grinding Area/Shop: Onboard Vessel

Risk Factor	**Work Phase 1** **Grind surface**	**Work Phase 2** **Repo-sition body**	**Work Phase 3** **Repo-sition/ adjust tool**	**Work Phase 4** **Inspect, rest**	**Work Phase 5** **Torch cut**	**Work Phase 6** **De-slag**
TOTAL Combination Posture Score	**3**	**1**	**2**	**2**	**3**	**2**
Common Posture Combinations (collapsed across work phases)						
Back	2	2	1			
Arms	3	1	1			
Legs	1	1	7			
Posture Repetition (% of working time)	35	31	24			
Back % of Working Time Score	2	2	1			
Arms % of Working Time Score	2	1	1			
Legs % of Working Time Score	1	1	1			

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Table 19. Shipfitter Grinding OWAS (continued)

Risk Factor	**Work Phase 1** **Grind surface**	**Work Phase 2** **Repo-sition body**	**Work Phase 3** **Repo-sition/ adjust tool**	**Work Phase 4** **Inspect, rest**	**Work Phase 5** **Torch cut**	**Work Phase 6** **De-slag**
Posture						
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2	1	2	2	2	2
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	3	1	1	1	3	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	1	7	1	1	1	1
Load/ Use of Force						
1 = weight or force needed is = or <10 kg (<22lbs) 2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs) 3 = weight or force > 20 kg (>44 lbs)	2	1	1	1	2	1
Phase Repetition						
% of working time (0,10,20,30,40,50,60,70,80,90,100)	11	24	18	12	24	1

Table 20. Shipfitter Grinding PLIBEL

PLIBEL Checklist, Kemmlert (1995)

Date/ Time: 4/13/00 Facility: _____
Task: Shipfitter Grinding Area/ Shop: Onboard Vessel

Section I: Musculoskeletal Risk Factors
Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	Y	Y	Y	Y	Y
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 20. Shipfitter Grinding PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	N				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	Y				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	N				N
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	Y				Y
f) handling below knee length	N				N
g) handling above shoulder height	Y				Y
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	N	N			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			

d) switches or keyboards?		N			

Table 20. Shipfitter Grinding PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	13	8	3	3	9
PERCENTAGE	50.0	72.7	37.5	37.5	42.9

Section II: Environmental / Organizational Risk Factors (Modifying) **Answer below questions, use to modify interpretation of musculoskeletal scores**	
18: Is there no possibility to take breaks and pauses?	N
19: Is there no possibility to choose order and type of work tasks or pace of work?	N
20: Is the job performed under time demands or psychological stress?	N
21:Can the work have unusual or expected situations?	N
22: Are the following present?	
a) cold	Y
b) heat	Y
c) draft	Y
d) noise	Y
e) troublesome visual conditions	Y
f) jerks, shakes, or vibration	Y
Environmental / Organizational Risk Factors Score	
SUM	6
PERCENTAGE	60.0

D9.5. Semi-Automatic Welder

Table 21. Semi-Automatic Welder RULA

Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

Day/Time: 4/13/00 | Facility:
Task: Semi-Automatic Welder | Area/Shop: Onboard Vessel

RULA: Posture Sampling Results				
RULA Component	**Frame # 46650** **Prepare machine**		**Frame # 48870** **Welding**	
	Specific	***RULA Score***	***Specific***	***RULA Score***
Shoulder Extension/ Flexion	mod flex	3	mod flex	3
Shoulder is Raised (+1)		1		0
Upper Arm Abducted (+1)		1		0
Arm supported, leaning (-1)		0		-1
Elbow Extension/ Flexion	neut	2	ext	1
Shoulder Abduction/ Adduction	mod abd	1	add	1
Shoulder Lateral/ Medial	lat	1	mod med	1
Wrist Extension/ Flexion	flx	2	neut	1
Wrist Deviation	neut	0	neut	0
Wrist Bent from Midline (+1)		0		0
Wrist Twist (1) In mid range Or (2) End of range		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		1
Arm and Wrist Force/Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		0		1

Table 21. Semi-Automatic Welder RULA (continued)

RULA Component	**Frame # 46650 Prepare machine**		**Frame # 48870 Welding**	
	Specific	***RULA Score***	***Specific***	***RULA Score***
Neck Extension/ Flexion		4		2
Neck Twist (+1)		1		0
Neck Side-Bent (+1)		1		0
Trunk Extension/ Flexion	mod flx	3	mod flx	3
Trunk Twist (+1)		1		0
Trunk Side Bend (+1)		1		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		1
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		1
Total RULA Score	**7**		**5**	
1 or 2 = Acceptable 3 or 4 = Investigate Further 5 or 6 = Investigate Further and Change Soon 7 = Investigate and Change Immediately				

B6. Wire Welder

Table 22. Wire Welder RULA

Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

Day/Time: 4/13/00 | Facility:
Task: Wire Welder | Area/Shop: Onboard Vessel

RULA: Posture Sampling Results

RULA Component	Frame # 15000 Welding kneeling		Frame # 25440 Welding standing		Frame # 16410 De-Slag		Frame # 28920 Prepare to weld		Frame # 16140 Change tool		Frame # 17280 Inspect	
	Specific	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*
Shoulder Extension/ Flexion	mod flex	3	sl flex	2	mod flex	3	neut	1	neut	1	sl flex	2
Shoulder is Raised (+1)		1		0		1		0		0		0
Upper Arm Abducted (+1)		1		1		0		0		0		0
Arm supported, leaning (-1)		0		-1		0		0		0		-1
Elbow Extension/ Flexion	neut	2	neut	2	neut	2	ext	1	ext	1	neut	2
Shoulder Abduction/ Adduction	mod abd	1	mod abd	1	neut	0	neut	0	neut	0	neut	0
Shoulder Lateral/ Medial	lat	1	lat	1	neut	0	neut	0	neut	0	neut	0
Wrist Extension/ Flexion	ext	2	ext	2	neut	1	neut	1	neut	1	neut	1
Wrist Deviation	ulnar	1	ulnar	1	ulnar	1	neut	0	neut	0	neut	0
Wrist Bent from Midline (+1)		0		0		0		0		0		0
Wrist Twist (1) In mid range Or (2) End of range		1		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		0		0		0		0
Arm and Wrist Force/ load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		2		1		0		1		0

Table 22. Wire Welder RULA (continued)

RULA Component	Frame # 15000 Welding kneeling		Frame # 25440 Welding standing		Frame # 16410 De-Slag		Frame # 28920 Prepare to weld		Frame # 16140 Change tool		Frame # 17280 Inspect	
	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score
Neck Extension/ Flexion		4		2		2		2		3		2
Neck Twist (+1)		0		0		0		0		0		0
Neck Side-Bent (+1)		0		0		0		0		0		0
Trunk Extension/ Flexion	neut	1	sl flx	2	sl flx	2	sl flx	2	sl flx	2	sl flx	2
Trunk Twist (+1)		0		0		0		0		0		0
Trunk Side Bend (+1)		0		0		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		0		0		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		2		1		1		1		1
Total RULA Score	**6**		**7**		**4**		**3**		**3**		**3**	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 23. Wire Welder Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
Moore and Garg (1995)

Date/ Time 4/13/00 ________ Facility:
Task : Wire Welder___ Area/ Shop: Onboard Vessel

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.					
Rating Criterion	**% MS** *(percentage of maximal strength)*	**Borg Scale** *(Compare to Borg Cr-10 Scale)*	**Perceived Effort**	**Rating**	**Multiplier**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**3.0**

Table 23. Wire Welder Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
% Duration of Exertion	< 10	1	0.5
= 100 x duration of all exertions (sec) / Total observation time (sec)	10 - 29	2	1.0
	30 - 49	3	1.5
= 100 x 584 (sec)/ 751 (sec) = 37	50 -79	4	2.0
	> or = 80	5	3.0
Duration of Exertion Multiplier			**1.5**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
Efforts per Minute	< 4	1	0.5
= number of exertions / total observation time (min)	4 - 8	2	1.0
	9 -14	3	1.5
= 12/12.52 = 0.95	15 -19	4	2.0
but welding is nearly static exertion, therefore, compromise at = 1.5	> or = 20	5	3.0
Efforts per Minute Multiplier			**1.5**

Table 23. Wire Welder Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	**Wrist Extension** *(Stetson et al, 1991)*	**Wrist Flexion** *(Stetson et al, 1991)*	**Ulnar Deviation** *(Stetson et al, 1991)*	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral (*estimated, based on RULAs performed)	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.5**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	**Compared to MTM** *(observed pace is divided by MTM's predicted pace and expressed as %)*	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	91 -100%	"normal" speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 23. Wire Welder Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
Duration of Task per Day (hrs)	< or = 1 hrs	1	0.25
= duration of task (hrs) + duration of task (hrs) + ...	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
= (estimate @ 2-4 hrs)	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**0.75**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**		**SI SCORE**
3.0 X	**1.5 X**	**1.5 X**	**1.5 X**	**1.0 X**	**0.75**	**=**	**7.6**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 24. Wire Welder UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
Lifshitz and Armstrong (1986)

Date/ Time: 4/13/00 Facility:
Task: Wire Welder Area/ Shop: Onboard Vessel
* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	No	Yes
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?		Y
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?		Y
6.3 Is the handle of the tool made from material other than metal?		Y
6.4 Is the weight of the tool below 4 kg (9lbs)?		Y
6.5 Is the tool suspended?	N	
TOTAL	**13 (59%)**	**9 (41%)**

Table 25. Wire Welder OWAS

OWAS: OVAKO Work Analysis System
Louhevaara and Suurnäkki (1992)

Procedure: Observe workers at intervals of 30-60 seconds. Record postures and forces over a representative period (~ 45 minutes)

Date/ Time: 4/13/00 Facility: _____
Task: Wire Welder Area/Shop: Onboard Vessel

Risk Factor	**Work Phase 1** **Welding kneeling**	**Work Phase 2** **Welding standing**	**Work Phase 3** **De-Slag**	**Work Phase 4** **Prepare to weld**	**Work Phase 5** **Change tool**	**Work Phase 6** **Inspect**
TOTAL Combination Posture Score	**1**	**2**	**2**	**2**	**2**	**2**
Common Posture Combinations (collapsed across work phases)						
Back	1	2				
Arms	3	1				
Legs	6	2				
Posture Repetition (% of working time)	11	86				
Back % of Working Time Score	1	3				
Arms % of Working Time Score	1	1				
Legs % of Working Time Score	1	2				

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Table 25. Wire Welder OWAS (continued)

Risk Factor	**Work Phase 1** **Welding kneeling**	**Work Phase 2** **Welding standing**	**Work Phase 3** **De-Slag**	**Work Phase 4** **Prepare to weld**	**Work Phase 5** **Change tool**	**Work Phase 6** **Inspect**
Posture						
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	1	2	2	2	2	2
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	3	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	6	2	2	2	2	2
Load/ Use of Force						
1 = weight or force needed is = or <10 kg (<22lbs) 2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs) 3 = weight or force > 20 kg (>44 lbs)	2	2	1	1	1	1
Phase Repetition						
% of working time (0,10,20,30,40,50,60,70,80,90,100)	11	19	1	41	5	20

Table 26. Wire Welder PLIBEL

PLIBEL Checklist, Kemmlert (1995)

Date/ Time: 4/13/00 Facility: _____
Task: Wire Welder Area/ Shop: Onboard Vessel

Section I: Musculoskeletal Risk Factors
Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			N	N	N
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			Y	Y	Y
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			Y	Y	Y
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 26. Wire Welder PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	N				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	Y				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	N				N
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	Y				Y
f) handling below knee length	N				N
g) handling above shoulder height	Y				Y
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	N	N			N
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	N	N			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		N			
c) uncomfortable hand positions?		Y			

d) switches or keyboards?		N			

Table 26. Wire Welder PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	11	5	3	3	8
PERCENTAGE	42.3	45.5	37.5	37.5	38.1
Section II: Environmental / Organizational Risk Factors (Modifying) **Answer below questions, use to modify interpretation of musculoskeletal scores**					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	N				
20: Is the job performed under time demands or psychological stress?	N				
21:Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	Y				
b) heat	Y				
c) draft	Y				
d) noise	Y				
e) troublesome visual conditions	Y				
f) jerks, shakes, or vibration	N				
Environmental / Organizational Risk Factors Score					
SUM	5				
PERCENTAGE	50.0				

APPENDIX E

PRE-INTERVENTION QUALITATIVE ERGONOMIC

HAZARD ANALYSIS

WORK TASKS ANALYZED:

Bin Loading
Switchboard Hook-up
Cable Pulling
Shipboard Rigger
Insulation Cutter/Installer
Welder (Buildings)
Tank Grinders

E1. Bin Loading by Material Handlers in Assembly Area

E1.1. Process

Pre-cut shapes are shipped into the East End of the Panel line from off-site facilities in large metal shipping containers. Shipping containers are delivered by forklift and are placed into the Material Handling area by utilizing a hand operated pallet jack. Overall process is as follows:

1. Material Handlers remove individual pieces from the shipping containers and identifies hull, unit and job and other pertinent numbers. Quantity, size, and material are compared with shipping documents to assure accuracy.

Figure 1 Lifting steel out of shipping container

2. Once item has been identified it is carried and placed onto the appropriate shelve and location marked on receiving documentation.

Figure 2 Carry steel shape to rack

3. Shapes/pieces are then arranged on the shelves to allow easy retrieval by shipfitters working within the area.

4. Once item has been removed from the bin, checked in, and placed on the appropriate shelve, employee returns to the shipping container and the process repeats until bin has been emptied. This walking back to the shipping bin could be considered a rest break from material handling.

E1.2. Ergonomic Risk Factors for Bin Loaders (material handlers).

During the loading/unloading tasks, material handlers assumed significant forward trunk flexion $\geq$ 90 degrees. Shoulder flexion is performed when reaching into the bottom of the shipping containers. This is coupled with a forceful pinch grip that is magnified due to awkward wrist postures (wrist extension). Grip strength requirements are high due to size, weight, type of material handled and the wearing of leather work gloves. Lifting and carrying tasks are regularly performed. Weights of objects vary with dimensional differences. Neck extension is performed when unloading metal shipping bins. Forward neck and trunk flexion is performed when arranging shapes onto racks. While removing material from bins and stacking the material on racks, the bin loader experiences a number of ergonomic risk factors. These risk factors include awkward postures such as extreme lumbar flexion, as well as excessive loads to low back and shoulders.

E1.3. Ergonomic Analysis of Bin Loaders (material handlers).

Using several of the exposure assessment tools outlined above, an ergonomic analysis was performed for the bin loader. A Rapid Upper Limb Assessment was conducted for the bin loaders (E10.1 Table 1), analyzing four sub-tasks with unique postures. One of the four subtasks, lifting piece from bin, scored a 7 (investigate and change immediately) on a scale of 1 to 7. Two other subtasks, piece carrying and rack arranging, resulted in scores of at least 3 (investigate further). The final subtask of walking back to the bin was deemed Acceptable with a score of two out of seven.

A Strain Index analysis was performed for the bin loader (E10.1 Table 2) with the following results:

1) the Intensity of Exertion was rated as "Somewhat Hard" and given a multiplier score of 3 on a scale of 1 to 13

2) the Duration of the task was rated as 50 - 79 % of the task cycle, resulting in a

multiplier of 2.0 on a scale of 0.5 to 3.0

3) the Efforts per Minute were noted to be between 9 and 14, resulting in a multiplier of 1.5 on a scale of 0.5 to 3.0

4) the Hand/Wrist posture was rated as "Fair" resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0

5) the Speed of Work was rated as "Normal" resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0

6) the Duration of Task per Day was rated to be between 2 and 4 hours, resulting in a multiplier of 0.75 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 10.1. An SI score between 5-30 is correlated to an incidence rate of about 77 DUE injuries per 100 FTE. Thus, the Strain Index indicates that this task puts the worker at an increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the bin unloader (E10.1 Table 3), of the 14 possible responses, eleven were negative and three were positive. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the bin loader task (E10.1 Table 4), corrective measures were suggested for the specific sub-tasks of lifting a piece from bin and arranging rack.

The PLIBEL checklist for the bin loader task (E10.1 Table 5) reports a high percentage (~ 57- 62 %) of risk factors present for the neck, shoulder, upper back, and lower back, and a slightly lower percentage (~ 55 %) of risk factors present for the elbows, forearms, and hands. Several environmental and organizational modifying factors are present as well.

The NIOSH Lifting Equation was used to analyze the bin loading sub-task of manually picking material up from the bottom of the bin. The analysis (E10.1 Table 6) for this task suggests a recommended weight limit of 3.8 pounds, given the assumed posture and frequency of lifts. Given that the typical weight of the material removed from the bins is about 10 pounds, it is determined that 46 per cent of the male population and 4 per cent of the female population can perform this task without an increased risk of low back pain.

The University of Michigan 3D Static Strength Prediction Program was used to analyze the bin loading sub-task of manually picking material up from the bottom of the bin (E10.1 Table 7). Analysis of this sub-task resulted in estimated disc compression loads at the L5/S1 disc of 898 pounds, which exceeds the NIOSH Recommended Compression Limit of 770 pounds.

E2. Cable Connectors

E2.1. Process

Often referred to as Switchboard Installers, electricians identify route and hook up wire cable ends to large switchboard units located throughout the ship. Process involves identifying specific cables and attachment locations.

1. Cable is routed in, around and through bottom of switchboard to the specific hook-up/connection lug. Once at the desired location, wire ties are used to secure cable.

Figure 3 Working in bottom of switchboard

Figure 4 Arranging cables in Switchboard

2. Cable covering is removed and ends are striped back to permit good attachment of cable ends. The lugs are then secured to the switchboard units.

Figure 5 Cable ends are trimmed

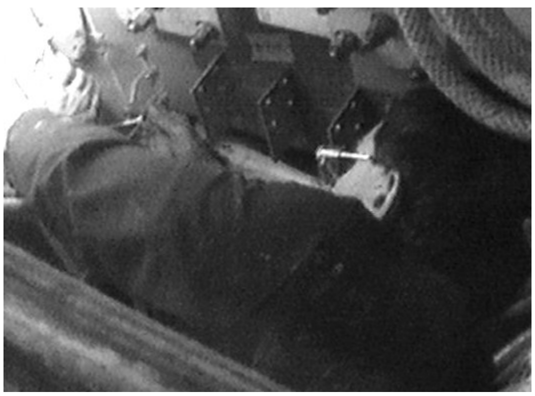

Figure 6 Cable secured to run with cable ties

3. Hook-up is then inspected to assure proper arrangement has been achieved in the switchboard.

E2.2. Ergonomic Risk Factors of Cable Connectors

During the switchboard hook-up process, static awkward postures of the upper extremities and trunk are common. Forceful exertions are performed often with the arms, wrist, and hands in a posture, which places the body part at a biomechanic disadvantage. Work is frequently performed in a confined work area, which hampers the electrician's ability to use good body mechanics when performing work tasks. This increases stress to the muscles being utilized thereby increasing fatigue and risk of developing a musculoskeletal disorder.

E2.3. Ergonomic Analysis of Cable Connectors

Using several of the exposure assessment tools outlined previously, an ergonomic analysis was performed for the cable connectors. A Rapid Upper Limb Assessment was conducted for the cable connectors (E10.2 Table 8), analyzing four sub-tasks with unique postures. One of the four subtasks, arranging/ tying cables, scored a 6 on a scale of 1 to 7 (investigate further and change soon). Another subtask, cable trimming, resulted in a score of 4 (investigate further). The final two subtasks of cable-tie trimming, and resting/ inspecting were determined to be "acceptable" with a score of two out of seven.

A Strain Index analysis was performed for the cable connector (E10.2 Table 9) with the following results:

1) the Intensity of Exertion was rated as “Somewhat Hard” and given a multiplier score of 3 on a scale of 1 to 13

2) the Duration of the task was rated as greater or equal to 80% of the task cycle, resulting in a multiplier of 3.0 on a scale of 0.5 to 3.0

3) the Efforts per Minute were noted to be nearly static, resulting in a multiplier of 3.0 on a scale of 0.5 to 3.0

4) the Hand/Wrist posture was rated as “Fair”, resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0

5) the Speed of Work was rated as “Normal”, resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0

6) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a multiplier of 1.00 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 40.5. An SI score between 31-60 is correlated to an incidence rate of about 106 DUE injuries per 100 FTE. Thus, the Strain Index indicates that this task puts the worker at a substantially increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the cable connector (E10.2 Table 10), of the 21 possible responses, twelve were negative and nine were positive. Again, negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the cable connector task (E10.2 Table 11), no corrective measures were suggested for any the specific sub-tasks comprising cable connecting. The PLIBEL checklist for the cable connector task (E10.2 Table 12) reports a high percentage (~ 73 %) of risk factors present for the elbows, forearms, and hands, and a low to moderate percentage (~ 39 %) of risk factors present for the neck, shoulder, and upper back. Several environmental and organizational modifying factors are present as well.

E3. Cable Pullers

E3.1. Process

Multiple lines of cable varying in length, size and weight are pulled by hand throughout areas of the ship. The larger cable pulls are performed in-groups numbering as high as 20. Size of the crew is largely dependent on size, length, and routing and final location of cable. Both 1.5 inch (approximated dimension) and .75 inch cable pulling was analyzed. Cable runs are located overhead, along bulkheads, and below deck plate level. All cable is secured into cable trays and tagged whenever passing through a bulkhead or deck. When running from one deck to another, the cable passes through transits, which are later packed to assure an air/water tight seal.

Following process was observed for the 1.5-inch cable and involves working at and below deck plate level:

1. Cable is routed fed through cable trays until final destination is reached. Photo below depicts this task being performed while sitting. This is due to the below deck plate location of cable tray.

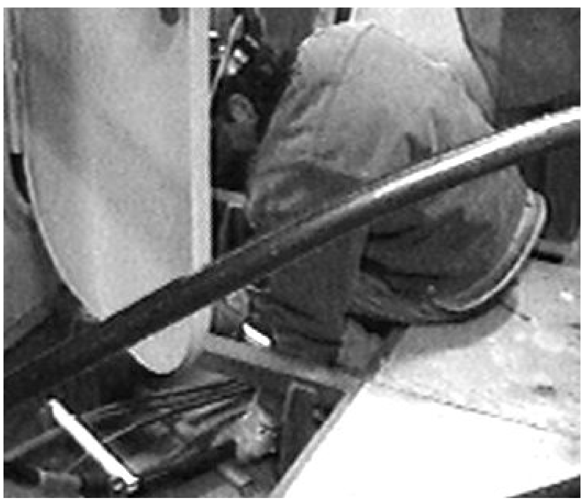

Figure 7 Feeding 1.5 inch cable through cable tray

2. Cable routing often involves manipulating cable already run through the tray and/or feeding through trays in hard to reach locations. The result is poor postures as depicted in the photo below.

Figure 8 Squatting to run cable below deck plate level

3. Once cable reaches the transit, or bulkhead oval (cutout), it is routed through the structure and secured using cable ties. This often requires forceful pulling while in an awkward posture.
4. When cable reaches its final destination process repeats. Employees take rest breaks as needed.

The identical process is used when pulling smaller cable, except that, one person is usually assigned to the job. The photos below depict the process performed when routing a .75" diameter cable through the overhead.

1. Cable is pulled through existing cable trays located in the overhead. The fact that it is difficult to orient the worker in relationship to the work space in the photo below is indicative of the confined areas cable pullers work in on a regular basis.

Figure 9 Pulling cable in confined space

2. Cable must be fed through the cable trays. This is usually performed one tray at a time when space within the cable run is limited.

Figure 10 Feeding cable through overhead trays

3. During the process, the cable puller must frequently adjust the cable to permit it to pass through the cable tray. Photo below depicts this being performed in an overhead position. As the number of cables within the tray increase, force required significantly increases. This often results in the workers reorienting themselves to obtain the necessary leverage to perform work task.

Figure 11 Adjusting cable in overhead posture

4. Whenever cable passes through a bulkhead or deck it must be labeled for identification purposes. Label is pre-cut and marked. Small banding device is used to secure label to cable. Cables must also be tied to the cable tray utilizing plastic ties. Photo below depicts typical postures assumed when labeling and securing to cable trays.

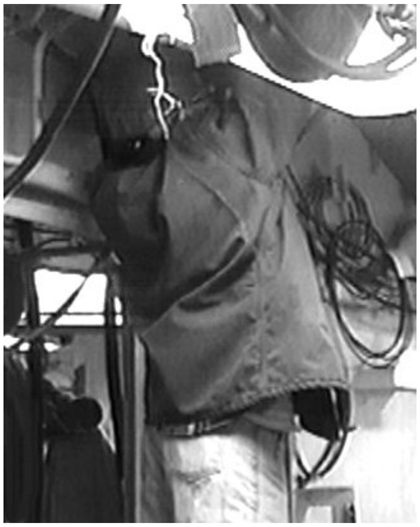

Figure 12 Installing metal tag/label onto cable

E3.2. Ergonomic Risk Factors of Cable Pullers

Multiple risk factors were observed during the pulling process. Forceful exertions where common when handling the larger cable. This is significantly magnified due to postures assumed while engaged in the pulling process. When pulling cable below deck plate level, forward neck and trunk flexion is common. This is due to location of cable trays and specific route of the cable run. These postures can be static in nature with force being exerted while at a biomechanic disadvantage.

When pulling cable overhead, significant moment loads are placed on the shoulder and low back. Shoulder flexion and neck extension is common when pulling cable overhead with force being exerted at arm length. This is a very physically demanding job with regard to force exerted.

E3.3. Ergonomic Analysis of Cable Pullers

Cable Pullers (1.5 A diameter cable)

Using several of the exposure assessment tools outlined previously, separate ergonomic analyses were performed for the cable pullers working with 1.5" diameter and .75 A diameter cable. A Rapid Upper Limb Assessment was conducted for the 1.5" diameter cable pulling task (E10.3 Table 13), analyzing four sub-tasks with unique postures. Two of the four subtasks, feeding cable below feet while sitting and feeding cable below feet while squatting, scored 7's on a scale of 1 to 7 (investigate and change immediately). Another subtask, arranging cable in conduit, resulted in a score of 4 (investigate further). The final subtask of changing position was determined to be "acceptable" with a score of two out of seven.

A Strain Index analysis was performed for the cable connector (1.5" diameter) (E10.3 Table 14) with the following results:

1) the Intensity of Exertion was rated as " Hard" and given a multiplier score of 6 on a scale of 1 to 13
2) the Duration of the task was rated as equal to 60% of the task cycle, resulting in a multiplier of 2.0 on a scale of 0.5 to 3.0
3) the Efforts per Minute were determined to be 2.4, but the task was rather static so the multiplier was set to 1.0 on a scale of 0.5 to 3.0
4) the Hand/Wrist posture was rated as "Fair" resulting in a multiplier of 1.5 on a scale

of 1.0 to 3.0

5) the Speed of Work was rated as “Normal” resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0

6) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a multiplier of 1.00 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 18. An SI score between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE. Thus, the Strain Index indicates that 1.5" cable pulling puts the worker at an increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the 0.75" diameter cable pulling task, (E10.3 Table 15), of the 18 possible responses, nine were negative and eight were positive. Again, negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the 1.5" diameter cable pulling task (E10.3 Table 16), corrective measures were suggested for a number of the specific sub-tasks, including feeding cable below feet while sitting and squatting, changing position, and arranging cable in conduit.

The PLIBEL checklist for the 1.5" diameter cable pulling task (E10.3 Table 17) reports a very high percentage (~ 82 %) of risk factors present for the elbows, forearms, and hands, and a high percentage (~ 73 %) of risk factors present for the neck, shoulder, upper back, and lower back. A moderate percentage (~ 50 %) of risk factors were also reported for the feet, knees and hips. Several environmental and organizational modifying factors are present as well.

Cable Pullers (0.75 A diameter cable)

A Rapid Upper Limb Assessment was conducted for the 0.75" diameter cable pulling task (E10.3 Table 18), analyzing four sub-tasks with unique postures. Two of the five subtasks, pulling cable and feeding cable, scored 7's (investigate and change immediately) on a scale of 1 to 7. Two other subtasks, adjusting cable and tying cables, resulted in scores of 5 (investigate further and change soon). The final subtask of changing position scored a 3 (investigate further). A Strain Index analysis was performed for the cable connector (0.75" diameter) (E10.3 Table 19) with the following results:

1) the Intensity of Exertion was rated as "Hard" and given a multiplier score of 6 on a scale of 1 to 13
2) the Duration of the task was rated as equal to 44% of the task cycle, resulting in a multiplier of 1.5 on a scale of 0.5 to 3.0
3) the Efforts per Minute were determined to be 1.6, resulting in a multiplier of 0.5 on a scale of 0.5 to 3.0
4) the Hand/Wrist posture was rated as "Fair" resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0
5) the Speed of Work was rated as "Normal" resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0

6) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a multiplier of 1.00 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 6.8. An SI score between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE. Thus, the Strain Index indicates that 0.75" cable pulling puts the worker at an increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the 0.75" diameter cable pulling task, (E10.3 Table 20), of the 20 possible responses, fourteen were negative and five were positive. Again, negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the 0.75" diameter cable pulling task (E10.3 Table 21), corrective measures were suggested for only one specific sub-task, tying cable.

The PLIBEL checklist for the 0.75" diameter cable pulling task (E10.3 Table 22) reports a very high percentage (~ 82 %) of risk factors present for the elbows, forearms, and hands, and a moderate to high percentage (~ 58 %) of risk factors present for the neck, shoulder, upper back. Lower percentages of risk factors were also reported for the feet, knees and hips (~ 50 %), and low back (~ 53 %). Several environmental and organizational modifying factors are present as well.

E4. Equipment Load-In by Shipboard Riggers

E4.1. Process

Equipment is lifted off of the transportation vehicle via large gantry crane and lowered into the ship. Depending on the final location of equipment and location of access hole, degree of manual manipulation of the object will vary. Two groups of Riggers exist within the shipyard. Those who work with the Gantry Crane Operators are often referred to as Dock Riggers. Their job responsibilities include rigging loads safely and being in visual and/or verbal contact with crane operator. Some truck drivers also rig up lifts. The employees who perform work tasks within the ship i.e. moving equipment through compartments are often referred to as Shipboard Riggers. Once the equipment is unhooked from the crane, Shipboard Riggers are responsible for getting the equipment/item to its final position. While we looked at both Dock and Shipboard Riggers, by far the shipboard employees perform the more physically demanding group of job tasks. Overall processes from Dock Riggers to Shipboard Riggers are as follows:

1. Equipment is lowered into an access hole located on the bow. A tag line is used to safety guide the load down to the Shipboard Riggers located below deck.

Figure 13 Cabinet being lowered to bottom deck

2. Photo below depicts Shipboard Riggers rolling equipment into the general vicinity of its final destination. Low cart rollers are very effective for moving equipment over flat decks with no lips or protrusions. Unfortunately, only a few areas are suitable for this mode of transport.

Figure 14 Equipment being moved on low cart

3. Once equipment/item is close to its final destination, or needs to move off of the low profile cart, it is slide across the deck as depicted in the photo below. Again, ability to perform this task is dependent on floor covering and the degree of friction (coefficient) between the item and the floor.

Figure 15 Sliding equipment off low cart

4. When feasible, shipboard riggers place a one-inch pipe under the equipment permitting it to be rolled with less effort.

Figure 16 Rolling equipment onto one-inch pipe

Figure 17 Rolling equipment with one-inch pipe

5. To place or remove pipe roller from underneath the equipment, the item being moved must be tilted on one end at an angle, which permits the roller device to be set. The photo below depicts this task being performed.

Figure 18 Equipment tilted to remove pipe roller

6. Once equipment/item is in place, process repeats itself until truck is unloaded.

E4.2. Ergonomic Risk Factors for Shipboard Riggers During Equipment Load-In

Shipboard Riggers perform forceful manual material handling on a frequent basis. This includes forceful push/pull, lift and at times carry. These tasks are often performed while in awkward postures (shoulder and wrist extension while in a kneeling posture with a forward flexed trunk in axial rotation with a lateral bend). These poor postures greatly increase the force required to perform work task. Magnitude of risk factor is determined by ship/deck landing point, item being moved, ship/deck configuration and final location of equipment. At times Shipboard Riggers carry heavy mechanical lift assist devices on board to get heavier equipment through shipboard doorways.

E4.3. Ergonomic Analysis of Shipboard Riggers During Equipment Load-Out

Using several of the exposure assessment tools outlined previously, an ergonomic analysis was performed for the shipboard riggers during equipment load-in. A Rapid Upper Limb Assessment was conducted for the shipboard riggers (E10.4 Table 22), analyzing six sub-tasks with unique postures. Two of the six subtasks, rolling equipment on pipe rollers and tilting equipment, scored 7's (investigate and change immediately) on a scale of 1 to 7. Another subtask, sliding equipment, resulted in a score of 6 (investigate further and change soon). Two other subtasks, lowering equipment through hatch and rolling equipment on low profile cart, resulted in scores of at least 3 (investigate further). The final subtask of waiting for the new load was the only one deemed "acceptable" with a score of one out of seven.

A Strain Index analysis was performed for the bin loader (E10.4 Table 23) with the following results:

1) the Intensity of Exertion was rated as "Hard" and given a multiplier score of 6 on a scale of 1 to 13
2) the Duration of the task was rated as 51 % of the task cycle, resulting in a multiplier of 2.0 on a scale of 0.5 to 3.0

3) the Efforts per Minute were noted to be 2.2, resulting in a multiplier of 0.5 on a scale of 0.5 to 3.0

4) the Hand/Wrist posture was rated as "Good" resulting in a multiplier of 1.0 on a scale of 1.0 to 3.0

5) the Speed of Work was rated as "Normal" resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0

6) the Duration of Task per Day was rated to be between 2 and 4 hours, resulting in a multiplier of 0.75 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 4.5. An SI score SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE. Thus, the Strain Index indicates that this task puts the shipboard rigger at an minimal risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the shipboard rigger (E10.4 Table 24), of the 16 possible responses, eight were negative and eight were positive. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the shipboard rigger equipment loading task (E10.4 Table 25), corrective measures were suggested for the specific sub-tasks of rolling equipment on pipe rollers, tilting equipment, sliding equipment, and rolling equipment on low profile cart.

The PLIBEL checklist for the shipboard rigger equipment loading task (E10.4 Table 26) reports a high percentage (64%) of risk factors present for the elbows, forearms, and hands. Slightly lower percentages of risk factors present for the neck, shoulder, upper back (~ 57 %), and low back (~50%) were also reported. Several environmental and organizational modifying factors are present as well.

The University of Michigan 3D Static Strength Prediction Program was used to analyze the shipboard rigger equipment loading subtask of tilting equipment (E10.4 Table 28). Analysis of this sub-task resulted in estimated disc compression loads at the L5/S1 disc of 789 pounds, which exceeds the NIOSH Recommended Compression Limit of 770 pounds.

E5. Insulation Workers

E5.1. Process

Insulators usually work in teams consisting of one Installer and one Cutter. The installer measures the area to be covered and relays this information to the cutter, who measures, marks and cuts the piece of insulation to size. The piece is then handed up or over to the installer who pushes the insulation into place, piercing the insulation material onto the insulation stud. The installer then installs a cap over the end of the stud securing it with a hammer strike. Installers and cutters will trade places from day to day. It is common for installers to work off of stepladders when performing overhead and some bulkhead installation. Cutters usually set up makeshift workbenches using several boxes of the insulation and/or sawhorses. Most of the insulation is a foam type of material, however, some fiberglass is still used. Sheets are usually 2" x 4".

Cutters

Cutters measure marks and cut pieces of insulation to size. The piece is then handed up or over to the installer.

1. Photo below depicts the cutter measuring and marking a sheet of foam insulation from information received from the installer.

Figure 19 Cutter measuring piece

2. Insulation is then cut using a slight sawing motion with a special knife.

Figure 20 Cutting foam insulation

3. Once the piece has been cut to size, it is handed up or over to the installer.

Figure 21 Cutting operation

4. Cutter then sets up another piece to be fitted and the process repeats.

Figure 22 Cutter handing cut piece to installer

Installers

Installers measure area to be covered and verbally relay information to cutter. Once insulation has been cut to size, it is secured to the overhead and/or bulkhead using stud caps, which must be snapped/hammered into place.

1. Cut insulation is fit into area to be covered.

Figure 23 Insulation fit into place

2. Installer measures area to be cut.

Figure 24 Next area is measured

3. Insulation is trimmed (if necessary) and stud/tie holes are cut.

Figure 25 Cutting holes for studs

4. Stud caps are then secured by a hammer and process repeats.

Figure 26 Installing caps on studs

E5.2. Ergonomic Risk Factors for Insulation Workers

Insulation Cutters Ergonomic Risk Factors

The key risk factors for insulation cutters are moderate forward head/neck postures. These postures are assumed when transferring measurements to the insulation piece and during the cutting process. Depending on grip used on knife ulnar deviation of the wrist is common however, force exerted is light.

Insulation Installers Ergonomic Risk Factors

Working at and/or above shoulder level is common when installing insulation in the overhead. Shoulder flexion with the wrist in extension is common when performing overhead work. Neck is also in significant extension when looking/working in the overhead. While force exertions are minimal, stress created by awkward postures of the upper extremities and neck is significant. If the area to be covered is obstructed by piping, ventilation runs, and/or equipment, awkward posture of the trunk are assumed

E5.3. Ergonomic Analysis of Insulation Workers

Insulation Cutters Ergonomic Analysis

Using several of the exposure assessment tools outlined previously, an ergonomic analysis was performed for the insulation cutters. A Rapid Upper Limb Assessment was conducted for the insulation cutters (E10.5 Table 29), analyzing five sub-tasks with unique postures. One of the five subtasks, cutting insulation, scored a 5 (investigate further and change soon) on a scale of 1 to 7. Another subtask, measuring insulation, resulted in a score of 3 (investigate further). The final subtasks of changing tools, passing insulation, and moving insulation, were deemed "acceptable" with a scores of two out of seven.

A Strain Index analysis was performed for the insulation cutter (E10.5 Table 30) with the following results:

1) the Intensity of Exertion was rated as "Light" and given a multiplier score of 1 on a scale of 1 to 13
2) the Duration of the task was rated as 41 % of the task cycle, resulting in a multiplier of 1.5 on a scale of 0.5 to 3.0
3) the Efforts per Minute were noted to be 2.4, resulting in a multiplier of

0.5 on a scale of 0.5 to 3.0

4) the Hand/Wrist posture was rated as “Fair” resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0

5) the Speed of Work was rated as “Normal” resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0

6) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a multiplier of 1.00 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 1.1. An SI score SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE. Thus, the Strain Index indicates that this task puts the worker at an minimal risk of developing a distal upper extremity injury.
In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the insulation cutter (E10.5 Table 31), of the 22 possible responses, fourteen were negative and eight were positive. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the insulation cutter (E10.5 Table 32), corrective measures were only suggested for the specific sub-task of cutting insulation.

The PLIBEL checklist for the insulation cutter (E10.5 Table 33) reports a moderate percentage (46%) of risk factors present for the elbows, forearms, and hands. Several environmental and organizational modifying factors are present as well.

Insulation Installers Ergonomic Analysis

Using several of the exposure assessment tools outlined previously, an ergonomic analysis was performed for the insulation installers. A Rapid Upper Limb Assessment was conducted for the insulation installers (E10.5 Table 34), analyzing six sub-tasks with unique postures. Four of the six subtasks, placing insulation overhead, measuring insulation overhead, trimming insulation/ cutting tie holes, and hammering stud caps, scored at least 5's (investigate further and change soon) on a scale of 1 to 7. Another subtask, repositioning body/ ladder, resulted in a score of 3 (investigate further). The final subtask of waiting for the cutter was the only one deemed "acceptable" with a score of two out of seven.

A Strain Index analysis was performed for the insulation installer (E10.5 Table 35) with the following results:

1) the Intensity of Exertion was rated as "Somewhat Hard" and given a multiplier score of 3 on a scale of 1 to 13
2) the Duration of the task was rated as 65 % of the task cycle, resulting in a multiplier of 2.0 on a scale of 0.5 to 3.0

3) the Efforts per Minute were noted to be 2, but since they were rather static, a multiplier of 1.0 on a scale of 0.5 to 3.0 was assigned

4) the Hand/Wrist posture was rated as “Bad” resulting in a multiplier of 2.0 on a scale of 1.0 to 3.0

5) the Speed of Work was rated as “normal” resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0

6) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a multiplier of 1.00 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 12. An SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE. Thus, the Strain Index indicates that this task puts the insulation installer at moderate risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the insulation installer (E10.5 Table 36), of the 22 possible responses, fifteen were negative and seven were positive. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the insulation installer task (E10.5 Table 37), corrective measures were suggested for the specific sub-tasks of placing insulation overhead, measuring insulation overhead, trimming insulation/ cutting tie holes, and hammering stud caps.

The PLIBEL checklist for the insulation installer task (E10.5 Table 38) reports a high percentage (63%) of risk factors present for the feet, knees and hips. Slightly lower percentages of risk factors present for the low back (~ 57 %), neck, shoulder, upper back (~ 50%), and elbows, forearms, and hands (~ 46%) were also reported. Several environmental and organizational modifying factors are present as well.

E6. Wire Welding in the Panel Line Assembly Area

E6.1. Process

Welders working in the Panel Line building are responsible for welding sheets and other structural members to form bulkheads, decks and overhead units. Items to be welded have been tacked into place by the Shipfitters. If necessary, welders grind the area to remove any foreign debris and using semi-automatic welding equipment performs the welding operation. Once a bead has been run, it is cleaned using a slag hammer, offset wire brush or other pneumatic equivalent. Most work in the Panel Line is performed in the downward position. It is common for welders to sit, kneel, crouch, bend and even lay down on the steel when welding.

Photo below shows welder grinding areas prior to welding process. Posture is typical of those assumed by welders in the panel line building.

Figure 27 Welder dressing-up weld

Welder assumes a forward flexed posture on one knee to perform welding tasks. Again this is a very typical posture assumed by welders working at deck plate level.

Figure 28 Welding while kneeling

Once grinding and welding process has been accomplished photo below depicts welder rearranging temporary ventilation (sucker tube), air hose, and welding leads for the next job. Welders are required to position sucker tubes to remove welding fumes/smoke.

Figure 29 Welder repositioning equipment

E6.2. Ergonomic Risk Factors for Wire Welders in the Panel Line Assembly Area

Key risk factors include static awkward postures of the back, neck and arms. Many of these postures could be considered extreme, as many of the joints are at difficult/extreme angles, which increases force requirements and heighten muscle fatigue. Static awkward postures of the wrist and hand (bi-planer posture of wrist extension while in ulnar deviation) can be assumed when holding onto semi-automatic welding gun. While welders are instructed not to snap the neck forward when lowering their welding hood, several such actions were observed. This places high shear loads on the cervical discs. Some external contact forces are realized in the knees, hands and arms. Static kneeling places high stress on the patella and is a key risk factor in the development of patella-femoral pain.

E6.3. Ergonomic Analysis of Wire Welders in the Panel Line Assembly Area

Using several of the exposure assessment tools outlined above, an ergonomic analysis was performed for the panel line welder. A Rapid Upper Limb Assessment was conducted for the panel line welder (E10.6 Table 39), analyzing six sub-tasks with unique postures. One of the six subtasks, wire welding kneeling, scored a 7 (investigate and change immediately) on a scale of 1 to 7. Another subtask, grinding crouched/ kneeling, resulted in a score of 5 (investigate further and change soon). Three other subtasks, inspecting, re-arranging equipment, and re-positioning body, resulted in scores of 3 (investigate further). The final subtask of changing tool was deemed "acceptable" with a score of two out of seven.

A Strain Index analysis was performed for the panel line wire welder (E10.6 Table 40) with the following results:

1) the Intensity of Exertion was rated as "Somewhat Hard" and given a multiplier score of 3 on a scale of 1 to 13
2) the Duration of the task was rated as 54 % of the task cycle, resulting in a multiplier of 2.0 on a scale of 0.5 to 3.0
3) the Efforts per Minute were noted to be 3, but since the exertions were nearly static, the multiplier was set to 1.5 on a scale of 0.5 to 3.0
4) the Hand/Wrist posture was rated as "Fair" resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0
5) the Speed of Work was rated as "Normal" resulting in a multiplier of 1.0 on a scale of

1.0 to 2.0

6) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a multiplier of 1.00 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 27. An SI score between 5-30 is correlated to an incidence rate of about 77 DUE injuries per 100 FTE. Thus, the Strain Index indicates that this task puts the worker at an increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the panel line welder (E10.6 Table 41), of the 21 possible responses, twelve were negative and nine were positive. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the panel line welder task (E10.6 Table 42), corrective measures were suggested for the specific sub-tasks of inspecting, wire welding kneeling, re-arranging equipment, and changing position.

The PLIBEL checklist for the panel line welder task (E10.6 Table 43) reports a moderately high percentage of risk factors present for the elbows, forearms, and hands (~ 55 %) and slightly lower percentages for the neck, shoulder, upper back (~ 50 %), and lower back (~ 48 %). Several environmental and organizational modifying factors are present as well.

E7. Shipboard Tank Grinding

E7.1. Process

Responsibilities include removing paint, rust and other foreign objects from tanks, the bilge, bulkheads etc. Main purpose is to prepare surface for painting. In some areas all paint is removed while in others a feathered edge is created. Tank grinders use multiple pneumatic tools, depending on specific task to be completed and available work space. The most common pneumatic tools include the 3 & 5-inch disc sanders, offset wire brush and needle gun. After area has been ground, it is cleaned using various cleaning solutions.

1. Photo is of a tank grinder utilizing a 5-inch disc sander, which is one of the most commonly, used tools within the shipyard. The tool itself is a modified drill with backing pad attached.

Figure 30 5-inch disc sander

2. A 3-inch disc grinder is used on the underneath sides of stiffeners and other structural members as well as in tight/hard to reach spaces.

Figure 31   3 inch disc sander

3. Photo below shows an offset wire brush being used. This tool is used commonly on pipes, in corners on welds, etc.

Figure 32   Pneumatic Wire brush

4. A needle gun is commonly used to chip off paint and/or slag from welds. Photo below shows a needle gun in use.

Figure 33 Pneumatic Needle Gun

E7.2. Ergonomic Risk Factors for Shipboard Tank Grinding

Key risk factors that were observed with the Tank Grinders were the awkward static postures of the trunk and upper extremities assumed while performing job tasks. Work postures are at times dictated by the amount of space available for the employee to perform job tasks. Static griping of pneumatic/vibrating tools is performed on a regular basis. Bi-planer wrist postures (flexion and/or extension with ulnar deviation) are common. Employees must wear full-face negative pressure respirators while engaged. Some external contact forces are realized in the knees, hands and arms. Static kneeling places high stress on the patella and is a key risk factor in the development of patella-femoral pain.

E7.3. Ergonomic Analysis of Shipboard Tank Grinding

Using several of the exposure assessment tools outlined above, an ergonomic analysis was performed for the shipboard tank grinder. A Rapid Upper Limb Assessment was conducted for the shipboard tank grinder (E10.7 Table 44), analyzing six sub-tasks with unique postures and forces.

Two of the six subtasks, grinding with a 3-inch grinder overhead and using wire brush, scored 7's (investigate and change immediately) on a scale of 1 to 7. Two other subtasks, grinding with 5-inch grinder and using needlegun, resulted in scores of at least 5 (investigate further and change soon). The final two subtasks of changing tool and changing grinding pad resulted in scores of 3 (investigate further).

A Strain Index analysis was performed for the shipboard tank grinder (E10.7 Table 45) with the following results:

1) the Intensity of Exertion was rated as "Hard" and given a multiplier score of 6 on a scale of 1 to 13
2) the Duration of the task was rated as 91 % of the task cycle, resulting in a multiplier of 3.0 on a scale of 0.5 to 3.0
3) the Efforts per Minute were noted to be nearly static, resulting in a multiplier of 3.0 on a scale of 0.5 to 3.0
4) the Hand/Wrist posture was rated as "Fair" resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0

5) the Speed of Work was rated as “Normal” resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0

6) the Duration of Task per Day was rated to be between 2 and 4 hours, resulting in a multiplier of 0.75 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 60.8. An SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE. Thus, the Strain Index indicates that this task puts the worker at an extremely increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the shipboard tank grinder (E10.7 Table 46), of the 22 possible responses, fourteen were negative and eight were positive. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the shipboard tank grinder (E10.7 Table 47), corrective measures were suggested for the specific sub-tasks of grinding with 5 inch and 3 inch grinders, wire brushing, and using the needle gun.

The PLIBEL checklist for the bin loader task (E10.7 Table 48) reports a very high percentage (~ 82 %) of risk factors present for the elbows, forearms, and hands and a high percentage (~ 63 %) for the feet, knees and hips. Slightly lower percentages of risk factors are present for the neck, shoulder, upper back (~ 54 %), and lower back (~ 53 %). Several environmental and organizational modifying factors are present as well.

E8. CONTROL TECHNOLOGY

Possible interventions and control technologies are mentioned briefly here. A more detailed report of possible interventions is in press.

E8.1. Bin Loading by Material Handlers Possible Interventions

Possible interventions for the bin loaders in the panel line assembly area include adjustable bins that raise and tilt the load towards the worker. Many inexpensive models of this type are commercially available. A hook-like tool for grasping individual workpieces may also help to bring the load closer to the material handler and also reduce the need for pinch-grip hand postures. Work practices of pre-sorting heavier items and emptying them by forklift onto a rotatable table top before handling may also be feasible.

E8.2. Shipboard Cable Connectors Possible Interventions

Possible interventions for the shipboard cable connectors include work practices which reduce the amount of cable preparation (stripping, tying etc...) at the switchboard, where the confined space limits work movements and postures. The use and maintenance of specialized cable tools may also reduce grip and other upper extremity forces.

E8.3. Shipboard Cable Pullers Possible Interventions

Possible interventions for the shipboard cable pullers include work rotation among pullers so that time spent in postures involving overhead work, kneeling, and back flexion are minimized and work practices to begin pulls in the middle of the cable rather than at the end (which requires pulling the entire length of cable in one pull). Semi-automated cable pulling systems are also commercially available and may be able to be integrated into the current manual pulling method.

E8.4. Equipment Load- In by Shipboard Riggers Possible Interventions

Possible interventions for the shipboard riggers during equipment load-in include the work practice of preparing the temporary deck surface to reduce the number of uneven plate and plywood surfaces that inhibit cart travel. Modified, low- profile ball bearing type carts or carts with lowered axles and adjustable wheels located outside the perimeter of the transported equipment may then be used to maneuver taller pieces of equipment into place. Such carts should reduce or eliminate the need for tilting the equipment on and off the pipe rollers and may also be able to be designed to allow for a smooth placement of the equipment into the retaining bracket.

E8.5. Shipboard Insulators Possible Interventions

Possible interventions for the shipboard insulators (cutters) include angled knives to maintain neutral wrist postures. Possible interventions for the shipboard insulators (installers) include an alternate insulation securing process involving semi-automatic stud guns or re-designed knives and hammers. Work rotation between the cutters and installers may also reduce the time spent in overhead postures by the worker performing the installation task.

E8.6. Possible Interventions for Welding in Buildings

Possible interventions for the panel line welders include the use of low profile, wheeled carts as movable seats for the welders to reduce back flexion and the need to assume kneeling postures. Such carts may be able to be custom designed to include upper body supports and knee supports that allow a variety of postures, such as semi sitting/ kneeling and leaning forward. Knee pads and thigh-supports to prevent overflexion of the knees during squatting are also commercially available.

E8.7. Shipboard Tank Grinders Possible Interventions

Possible interventions for the shipboard tank grinders include lighter tools that induce less vibration and the use of support devices such as spring returns for areas where extended vertical grinding is required. Process changes (e.g. weldable primer, more efficient and clean welding processes) to reduce the amount of required grinding may also be explored. Portable, self-contained abrasive blasting units may also be able to be used instead of manual grinding in some cases.

E9. REFERENCES

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E10. Analysis Tables

E10.1 Bin Loading Table 1. RULA

Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00		Panel line assembly	Bin Loading

RULA: Posture Sampling Results

RULA Component	**Frames # 30690 Walk back to bins**		**Frame # 30750 Lift piece from bin**		**Frame # 31140 Carry piece**		**Frame # 33690 Rack arranging**		**Frame # 34890 Rest**	
	Spec	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*
Shoulder Extension/ Flexion	neut	1	mod flex	3	neut	1	sl flex	2	neut	1
Shoulder is Raised (+1)		0		0		0		0		0
Upper Arm Abducted (+1)		0		0		0		0		0
Arm supported, leaning (-1)		0		0		0		0		0
Elbow Extension/ Flexion	ext	1	ext	1	neut	2	ext	1	ext	1
Shoulder Abduction/ Adduction	neut	0	add	1	neut	0	neut	0	neut	0
Shoulder Lateral/ Medial	neut	0	neut	0	neut	0	neut	0	neut	0
Wrist Extension/ Flexion	neut	1	ext	2	ext	2	ext	2	neut	1
Wrist Deviation	neut	0	ulnar	1	neut	0	neut	0	neut	0
Wrist Bent from Midline (+1)		0		0		0		0		0
Wrist Twist (1) In mid range or (2) End of range		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		1		1		0		0
Arm and Wrist Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		0		2		1		1		0

Table 1. Bin Loading RULA (continued)

RULA Component	Frames # 22890 Walk back to bins		Frame # 25050 Lift piece from bin		Frame # 23460 Carry piece		Frame # 133770 Rack arranging		Frame # 25530 Rest	
	Spec	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*
Neck Extension/ Flexion	**sl flx**	**2**	**ext**	**4**	sl flx	2	**mod flx**	**3**	**neut**	**1**
Neck Twist (+1)		**0**		**0**		**0**		**0**		**0**
Neck Side-Bent (+1)		**0**		**0**		**0**		**0**		**0**
Trunk Extension/ Flexion	neut	1	hyp flx	4	neut	1	mod flx	3	neut	1
Trunk Twist (+1)		0		1		0		0		0
Trunk Side Bend (+1)		0		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		1		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		2		1		1		1
Total RULA Score	**3**		**7**		**4**		**3**		**2**	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 2. Bin Loaders Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
Moore and Garg, 1995

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00		Panel line assembly	Bin Loading

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Circle the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	***% MS*** (percentage of maximal strength)	***Borg Scale*** (Compare to Borg Cr-10 Scale)	***Perceived Effort***	***Rating*** (circle)	***Multiplier***
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13
				Intensity of Exertion Multiplier (Fill in)	**3**

Table 2. Bin Loaders Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0

Worksheet: % Duration of Exertion = 100 x duration of all exertions (sec) Total observation time (sec) = 100 x 204 (sec)/ 268(sec) = 76	***Rating Criterion***	***Rating***	***Multiplier***
	< 10	1	0.5
	10 - 29	2	1.0
	30 - 49	3	1.5
	50 -79	4	2.0
	> or = 80	5	3.0
	Duration of Exertion Multiplier (Fill in)		2.0

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: Efforts per Minute = 100 x number of exertions Total observation time (min) = **69 /4.5 = 11.2**	***Rating Criterion***	***Rating***	***Multiplier***
	< 4	1	0.5
	4 - 8	2	1.0
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	5	3.0
	Efforts per Minute Multiplier (Fill in)		1.5

Table 2. Bin Loaders Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Circle the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	***Wrist Extension*** (Stetson et al, 1991)	***Wrist Flexion*** (Stetson et al, 1991)	***Ulnar Deviation*** (Stetson et al, 1991)	***Perceived Posture***	***Rating*** (circle)	***Multiplier***
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral (*estimated, based on RULAs performed)	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
					Hand/ Wrist Posture Multiplier (Fill in)	1.5

5. **Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.**				
Rating Criterion	**Compared to MTM** *(observed pace is divided by MTM's predicted pace and expressed as %)*	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	91 -100%	"normal" speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 2. Bin Loaders Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Circle the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet: Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate @ 2-4 hrs)	***Rating Criterion***	***Rating*** (circle)	***Multiplier***
	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
		Duration of Task per Day Multiplier (Fill in)	0.75

Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**		**SI SCORE**
3 X	**2** X	**1.5** x	**1.5** x	**1** x	**.75** x	**___=**	*** See 1st 10.1 Page**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 3. Bin loaders UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders

Lifshitz and Armstrong (1986)

Date/ Time	Facility	Area/Shop	Task
4/17/00		Panel line assembly	Bin loading

* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	No	Yes
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges	N	
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?	N	
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	n/a	n/a
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	n/a	n/a
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	n/a	n/a
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	n/a	n/a
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	n/a	n/a
6.3 Is the handle of the tool made from material other than metal?	n/a	n/a

6.4 Is the weight of the tool below 4 kg (9lbs)?	n/a	n/a
6.5 Is the tool suspended?	n/a	n/a
TOTAL	11(79%)	3 (21%)

Table 4. Bin Loaders OWAS

OWAS: OVAKO Work Analysis System

Louhevaara and Suurnäkki (1992)

Procedure: Observe workers at intervals of 30-60 seconds. Record postures and forces over a representative period (~ 45 minutes)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00		Panel line assembly	Bin loading

Risk Factor	**Work Phase1** **Walk back to bins**	**Work Phase 2** **Lift piece from bin**	**Work Phase 3** **Carry piece**	**Work Phase 4** **Rack arrangin g**	**Work Phase 5** **Rest**
TOTAL Combination Posture Score	1	2	1	2	1
Common Posture Combinations (collapsed across work phases)					
Back	1	4	1	2	1
Arms	1	1	1	1	1
Legs	7	2	7	2	2
Posture Repetition (% of working time)	42	48	26	2	8
BACK % of Working Time SCORE	**1**	**3**	**1**	**1**	**1**
ARMS % of Working Time SCORE	**1**	**1**	**1**	**1**	**1**
LEGS % of Working Time SCORE	**1**	**1**	**1**	**1**	**1**

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Table 4. Bin Loaders OWAS (continued)

Risk Factor	Work Phase1 Walk back to bins	Work Phase 2 Lift piece from bin	Work Phase 3 Carry piece	Work Phase 4 Rack arrangin g	Work Phase 5 Rest
Posture					
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	1	4	1	2	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	7	2	7	2	2
Load/ Use of Force					
1 = weight or force needed is = or <10 kg (<22lbs)	1	2	2	1	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)					
3 = weight or force > 20 kg (>44 lbs)					
Phase Repetition					
% of working time (0,10,20,30,40,50,60,70,80,90,100)	16	48	26	2	8

Table 5. Bin Loaders PLIBEL

PLIBEL Checklist, Kemmlert (1995)

Date/ Time	Facility	Area/Shop	Task
4/17/00		Panel line assembly	Bin Loading

Section I: Musculoskeletal Risk Factors

Methods of Application:

1) Find the injured body region, answer yes or no to corresponding questions

2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			N	N	N
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	n/a				n/a
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	Y				Y
d) severely twisted?	N				N
10: Is repeated/sustained work performed with neck:					
a) flexed forward?	N				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	Y				

11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	Y				Y
b) weight of load	Y				Y
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	Y				Y
e) handling beyond forearm length	Y				Y
f) handling below knee length	Y				Y
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	N				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		N			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 5. Bin Loaders PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	16	6	1	1	12
PERCENTAGE	61.5	54.5	12.5	12.5	57.1
Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	N				
20: Is the job performed under time demands or psychological stress?	N				
21:Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	Y				
b) heat	Y				
c) draft	Y				
d) noise	Y				
e) troublesome visual conditions	N				
f) jerks, shakes, or vibration	N				
Environmental / Organizational Risk Factors Score					
SUM	4				
PERCENTAGE	40.0				

Table 6. Bin Loaders NIOSH Lifting Equation Analysis

NIOSH Lifting Equation
(Waters, Putz-Anderson, Garg, and Fine, 1993)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00		**Panel line assembly**	**Bin Loading**

RESULTS	**ORIGIN**	**DESTINATION**
Recommended Weight Limit (RWL)	3.8 pounds	9.3 pounds
Lifting Index, LI (RWL/Load)	2.63	
Population Capable	Male = 46 % Capable Female = 4 % Capable	
ORIGIN VARIABLE	**ORIGIN VALUE**	**ORIGIN MULTIPLIER**
Horizontal Location, H	24 inches	0.42
Vertical Location, V	5 inches	0.81
Travel Distance, D	31 inches	0.88
Asymmetric Angle, A	0 degrees	1.00
Frequency, F	10 lifts/minute	0.26
Hand to Object Coupling, C	Fair	1.00
DESTINATION VARIABLE	**DESTINATION VALUE**	**DESTINATION MULTIPLIER**
Horizontal Location, H	12 inches	0.83
Vertical Location, V	36 inches	0.96
Travel Distance, D	31 inches	0.88
Asymmetric Angle, A	0 degrees	1.00
Frequency, F	10 lifts/minute	0.26
Hand to Object Coupling, C	Fair	1.00
Duration: 2 hours	**Average Object Weight: 10 pounds**	**Maximum Object Weight: 40 pounds**

Table 7. Bin Loader 3D Static Strength Prediction Program

3D Static Strength Prediction Program
(University of Michigan, 1997)

Date/ Time	Facility	Area/Shop	Task
4/17/00		Panel line assembly	Bin Loading

Work Elements: Bin Loading in Panel Line Area Frame Components	**Disc Compression (lbs) @ L5/S1 (Note: NIOSH Recommended Compression Limit (RCL) is 770 lbs)**
Bin loader picks up material from bottom of bin, approximate weight 40 pounds (frame # 30750)	898 pounds

E10.2 Table 8. Cable Connectors RULA

Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00		Shipboard	Cable Connecting

RULA Component	**Frames # 169620, 174300 Arrange/ tie cables**		**Frame # 176340 Change/ fix tools**		**Frame # 197490 Trim cable-ties**		**Frame # 192810 Rest/ Inspect**	
	Specific	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***
Shoulder Extension/ Flexion	sl flex	2	sl flex	2	sl flex	2	neut	1
Shoulder is Raised (+1)		0		0		1		0
Upper Arm Abducted (+1)		0		0		0		0
Arm supported, leaning (-1)		-1		-1		-1		0
Elbow Extension/ Flexion	neut	2	neut	2	flx	2	neut	2
Shoulder Abduction/ Adduction	neut	0	neut	0	neut	0	neut	0
Shoulder Lateral/ Medial	mod med	1	mod med	1	mod med	1	neut	0
Wrist Extension/ Flexion	ext	2	neut	1	ext	2	neut	1
Wrist Deviation	rad	1	neut	0	ulnar	1	neut	0
Wrist Bent from Midline (+1)		0		0		0		0
Wrist Twist (1) In mid range Or (2) End of range		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		0
Arm and Wrist Force/ load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		0		1		0

Table 8. Cable Connectors RULA (continued)

RULA Component	**Frames # 169620, 174300 Arrange/ tie cables**		**Frame # 176340 Change/ fix tools**		**Frame # 197490 Trim cable-ties**		**Frame # 192810 Rest/ Inspect**	
	Specific	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*
Neck Extension/ Flexion		1		1		1		1
Neck Twist (+1)		1		1		1		0
Neck Side-Bent (+1)		1		1		1		0
Trunk Extension/ Flexion	neut	1	neut	1	neut	1	neut	1
Trunk Twist (+1)		1		1		1		0
Trunk Side Bend (+1)		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		0		1		0
Total Rula Score	**6**		**2**		**4**		**2**	
1 or 2 = Acceptable **3 or 4 = Investigate Further** **5 or 6 = Investigate Further and Change Soon** **7 = Investigate and Change Immediately**								

Table 9. Cable Connectors Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
Moore and Garg, 1995

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00		Shipboard	Cable Connecting

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	***% MS (percentage of maximal strength)***	***Borg Scale (Compare to Borg Cr-10 Scale)***	***Perceived Effort***	***Rating***	***Multiplier***
Light	*< 10%*	*< or = 2*	*barely noticeable or relaxed effort*	*1*	*1.0*
Somewhat hard	*10 - 29%*	*3*	*noticeable or definite effort*	*2*	*3.0*
Hard	*30 - 49%*	*4 - 5*	*obvious effort; unchanged facial expression*	*3*	*6.0*
Very Hard	*50 - 79%*	*6 - 7*	*substantial effort; changes to facial expression*	*4*	*9.0*
Near Maximal	*> or = 80%*	*> 7*	*uses shoulder or trunk to generate force*	*5*	*13.0*
Intensity of Exertion Multiplier					*3.0*

Table 9. Cable Connectors Strain Index *(continued)*

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: *% Duration of Exertion* *= 100 x duration of all exertions (sec) / Total observation time (sec)* *= 100 x 889 (sec)/ 1075(sec)* *= 83*	*Rating Criterion*	*Rating*	*Multiplier*
	< 10	*1*	*0.5*
	10 - 29	*2*	*1.0*
	30 - 49	*3*	*1.5*
	50 -79	*4*	*2.0*
	> or = 80	*5*	*3.0*
Duration of Exertion Multiplier			*3.0*

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: *Efforts per Minute* *= number of exertions / total observation time (min)* *= nearly static, so set to 3.0*	*Rating Criterion*	*Rating*	*Multiplier*

	< 4	1	0.5
	4 - 8	2	1.0
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			3.0

Table 9. Cable Connectors Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	***Wrist Extension (Stetson et al, 1991)***	***Wrist Flexion (Stetson et al, 1991)***	***Ulnar Deviation (Stetson et al, 1991)***	***Perceived Posture***	***Rating***	***Multiplier***
Very Good	*0 -10 degrees*	*0 - 5 degrees*	*0 - 10 degrees*	*perfectly neutral*	*1*	*1.0*
Good	*11 - 25 degrees*	*6 - 15 degrees*	*11 -15 degrees*	*near neutral*	*2*	*1.0*
Fair	*26 -40 degrees*	*16 - 30 degrees*	*16 - 20 degrees*	*non-neutral (*estimated, based on RULAs performed)*	*3*	*1.5*
Bad	*41 - 55 degrees*	*31 - 50 degrees*	*21 -25 degrees*	*marked deviation*	*4*	*2.0*
Very Bad	*> 60 degrees*	*> 50 degrees*	*> 25 degrees*	*near extreme*	*5*	*3.0*
Hand/ Wrist Posture Multiplier						*1.5*

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	***Compared to MTM (observed pace is divided by MTM's predicted pace and expressed as %)***	***Perceived Speed***	***Rating***	***Multiplier***
Very Slow	*< or = 80%*	*extremely relaxed pace*	*1*	*1.0*
Slow	*81 - 90%*	*"taking one's own time"*	*2*	*1.0*
Fair	*91 -100%*	*"normal" speed of motion*	*3*	*1.0*

Fast	*101-115%*	*rushed, but able to keep up*	*4*	*1.5*
Very Fast	*> 115%*	*rushed, barely or unable to keep up*	*5*	*2.0*
Speed of Work Multiplier				*1.0*

Table 9. Cable Connectors Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet: Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate @ 4-8 hrs)	*Rating Criterion*	*Rating*	*Multiplier*
	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			1.00

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**		**SI SCORE**
3.0 X	**3.0 X**	**3.0 X**	**1.5 X**	**1.0 X**	**1.0**	**=**	**40.5**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 10. Cable Connectors UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders

Lifshitz and Armstrong (1986)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00		Shipboard	Cable Connecting

* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	**No**	**Yes**
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?		Y
1.4 Can the job be done without using gloves?		Y
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?	N	
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?		Y
3.6 Can the job be done without "clothes wringing" motion?	N	
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?		Y
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?		Y (cutter)
6.3 Is the handle of the tool made from material other than metal?		Y

6.4 Is the weight of the tool below 4 kg (9lbs)?		Y
6.5 Is the tool suspended?	N	
TOTAL	**12 (57%)**	**9 (43%)**

Table 11. Cable Connectors OWAS

OWAS: OVAKO Work Analysis System

Louhevaara and Suurnäkki (1992)

Procedure: Observe workers at intervals of 30-60 seconds. Record postures and forces over a representative period (~ 45 minutes)

Date/ Time	Facility	Area/Shop	Task
4/17/00		Shipboard	Cable Connecting

Risk Factor	Work Phase1 Arrange/ tie cables	Work Phase 2 Change / fix tools	Work Phase 3 Trim cable-ties	Work Phase 4 Rest/ Inspect
TOTAL Combination Posture Score	**1**	**1**	**1**	**1**
Common Posture Combinations (collapsed across work phases)				
Back	3	1		
Arms	1	1		
Legs	1	1		
Posture Repetition (% of working time)	83	5		
BACK % of Working Time SCORE	**3**	**1**		
ARMS % of Working Time SCORE	**1**	**1**		
LEGS % of Working Time SCORE	**1**	**1**		

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Table 11. Cable Connectors OWAS (continued)

Risk Factor	Work Phase1 Arrange/ tie cables	Work Phase 2 Change / fix tools	Work Phase 3 Trim cable-ties	Work Phase 4 Rest/ Inspect
Posture				
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	3	3	3	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	1	1	1	1
Load/ Use of Force				
1 = weight or force needed is = or <10 kg (<22lbs)	2	1	1	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)				
3 = weight or force > 20 kg (>44 lbs)				
Phase Repetition				
% of working time (0,10,20,30,40,50,60,70,80,90,100)	77	4	2	5

Table 12. Cable Connectors PLIBEL

PLIBEL Checklist, Kemmlert (1995)

Date/ Time	Facility	Area/Shop	Task
4/17/00		Shipboard	Cable Connecting

Section I: Musculoskeletal Risk Factors
Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			N	N	N
2: Is the space too limited for work movements or work materials?	Y	Y	Y	Y	Y
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	N				N
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	Y				Y
d) severely twisted?	N				N

Table 12. Cable Connectors PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	N				

b) bent sideways or mildly twisted?	Y				
c) severely twisted?	N				
d) extended backwards?	Y				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	N				N
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	N				N
f) handling below knee length	N				N
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	N	N			N
13: Is sustained work performed when one arm reaches forward or to the side without support?	N				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	N	N			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		Y			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 12. Cable Connectors PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	10	8	2	2	5
PERCENTAGE	38.5	72.7	25	25	23.8

Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores	
18: Is there no possibility to take breaks and pauses?	N
19: Is there no possibility to choose order and type of work tasks or pace of work?	N
20: Is the job performed under time demands or psychological stress?	N
21:Can the work have unusual or expected situations?	N
22: Are the following present?	
a) cold	N
b) heat	Y
c) draft	N
d) noise	Y
e) troublesome visual conditions	N
f) jerks, shakes, or vibration	N
Environmental / Organizational Risk Factors Score	
SUM	2
PERCENTAGE	20.0

E10.3 Table 13. Cable Pull (1.5") RULA

Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

Date/ Time	***Facility***	***Area/Shop***	***Task***
4/17/00		*Shipboard*	Cable Pulling (1.5")

RULA: Posture Sampling Results

RULA Component	**Frames # 22890 Feed cable below feet, sitting**		**Frame # 25050 Feed cable below feet squatting**		**Frame # 23460 Change position**		**Frame # 133770 Arrange cable in conduit**		**Frame # 25530 Rest**	
	Spec	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*
Shoulder Extension/ Flexion	sl flex	2	sl flex	2	sl flex	2	sl flex	2	sl flex	2
Shoulder is Raised (+1)		0		0		0		0		0
Upper Arm Abducted (+1)		0		0		0		0		0
Arm supported, leaning (-1)		0		0		0		0		0
Elbow Extension/ Flexion	ext	1	ext	1	ext	1	neut	2	ext	1
Shoulder Abduction/ Adduction	neut	0	neut	0	neut	0	neut	0	neut	0
Shoulder Lateral/ Medial	neut	0	neut	0	neut	0	lat	1	neut	0
Wrist Extension/ Flexion	ext	2	ext	2	neut	1	ext	2	neut	1
Wrist Deviation	ulnar	1	ulnar	1	neut	0	neut	0	neut	0
Wrist Bent from Midline (+1)		0		0		0		0		0
Wrist Twist (1) In mid range or (2) End of range		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		0		0
Arm and Wrist Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		3		3		0		1		0

Table 13. Cable Pull (1.5") RULA (continued)

RULA Component	**Frames # 22890** **Feed cable below feet, sitting**		**Frame # 25050** **Feed cable below feet squatting**		**Frame # 23460** **Change position**		**Frame # 133770** **Arrange cable in conduit**		**Frame # 22409** **Rest**	
	Spec	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*
Neck Extension/ Flexion	**sl flx**	**2**	**sl flx**	**2**	**neut**	**1**	**sl flx**	**2**	**sl flx**	**2**
Neck Twist (+1)		**1**		**1**		**0**		**1**		**0**
Neck Side-Bent (+1)		**0**		**0**		**0**		**0**		**0**
Trunk Extension/ Flexion	sl flx	2	mod flx	3	sl flx	2	sl flx	2	neut	1
Trunk Twist (+1)		1		1		0		0		0
Trunk Side Bend (+1)		1		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		3		3		1		1		0
Total RULA Score	**7**		**7**		2		4		**2**	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 14. Cable Pullers (1.5 inch diameter) Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
Moore and Garg, 1995

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00		Shipboard	Cable Pulling (1.5")

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.					
Rating Criterion	**% MS** *(percentage of maximal strength)*	**Borg Scale** *(Compare to Borg Cr-10 Scale)*	**Perceived Effort**	**Ratin g**	**Multiplie r**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewh at hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**6.0**

Table 14. Cable Pullers (1.5 inch diameter) Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: % Duration of Exertion = 100 x duration of all exertions (sec) / Total observation time (sec) = 100 x 91(sec)/ 152 (sec) = 60	**Rating Criterion**	**Rating**	**Multiplier**
	< 10	1	0.5
	10 - 29	2	1.0
	30 - 49	3	1.5
	50 -79	4	2.0
	> or = 80	5	3.0
Duration of Exertion Multiplier			**2.0**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0

Worksheet: Efforts per Minute = number of exertions / total observation time (min) = 6/2.5 = 2.4**, but rather static so set multiplier to 1.0**	**Rating Criterion**	**Rating**	**Multiplier**
	< 4	1	0.5
	4 - 8	2	1.0
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			**1.0**

Table 14. Cable Pullers (1.5 inch diameter) Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	**Wrist Extension** *(Stetson et al, 1991)*	**Wrist Flexion** *(Stetson et al, 1991)*	**Ulnar Deviation** *(Stetson et al, 1991)*	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral (*estimated, based on RULAs performed)	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.5**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	**Compared to MTM** *(observed pace is divided by MTM's predicted pace and expressed as %)*	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	91 -100%	"normal" speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 14. Cable Pullers (1.5 inch diameter) Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet: Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate @ 4-8 hrs)	***Rating Criterion***	***Rating***	***Multiplier***
	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**1.00**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.

Intensity of Exertion	Duration of Exertion	Efforts per Minute	Hand/ Wrist Posture	Speed of Work	Duration of Task		SI SCORE
6.0 X	**2.0 X**	**1.0 X**	**1.5 X**	**1.0 X**	**1.0**	**=**	**18**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 15. Cable Pullers (1.5 inch diameter) UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders

Lifshitz and Armstrong (1986)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00		Shipboard	Cable pulling (1.5")

* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	**No**	**Yes**
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?		Y
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?		Y
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?		Y
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	n/a	n/a
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	n/a	n/a
6.3 Is the handle of the tool made from material other than metal?	n/a	n/a

6.4 Is the weight of the tool below 4 kg (9lbs)?	n/a	n/a
6.5 Is the tool suspended?	n/a	n/a
TOTAL	**9 (53%)**	**8 (47%)**

Table 16. Cable Pullers (1.5 inch diameter) OWAS

OWAS: OVAKO Work Analysis System

Louhevaara and Suurnäkki (1992)

Procedure: Observe workers at intervals of 30-60 seconds. Record postures and forces over a representative period (~ 45 minutes)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00		Shipboard	Cable Pulling (1.5")

Risk Factor	**Work Phase1** **Feed cable below feet, sitting**	**Work Phase 2** **Feed cable below feet squatting**	**Work Phase 3** **Change position**	**Work Phase 4** **Arrange cable in conduit**	**Work Phase 5** **Rest**
TOTAL Combination Posture Score	**3**	**2**	**2**	**2**	**1**
Common Posture Combinations (collapsed across work phases)					
Back	4	2	2	2	1
Arms	1	1	1	1	1
Legs	1	4	7	1	1
Posture Repetition (% of working time)	16	26	7	11	3
BACK % of Working Time SCORE	**2**	**1**	**1**	**1**	**1**
ARMS % of Working Time SCORE	**1**	**1**	**1**	**1**	**1**
LEGS % of Working Time SCORE	**1**	**2**	**1**	**1**	**1**

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Table 16. Cable Pullers (1.5 inch diameter) OWAS (continued)

Risk Factor	Work Phase1 Feed cable below feet, sitting	Work Phase 2 Feed cable below feet squatting	Work Phase 3 Change position	Work Phase 4 Arrange cable in conduit	Work Phase 5 Rest
Posture					
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	4	2	2	2	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	1	4	7	1	1
Load/ Use of Force					
1 = weight or force needed is = or <10 kg (<22lbs) 2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs) 3 = weight or force > 20 kg (>44 lbs)	2	2	1	1	1
Phase Repetition					
% of working time (0,10,20,30,40,50,60,70,80,90,100)	16	26	7	11	3

Table 17. Cable Pullers (1.5 inch diameter) PLIBEL

PLIBEL Checklist, Kemmlert (1995)

Date/ Time	Facility	Area/Shop	Task
4/17/00		Shipboard	Cable Pulling (1.5")

Section I: Musculoskeletal Risk Factors
Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	Y	Y	Y	Y	Y
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			Y	Y	Y
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	Y				Y
d) severely twisted?	N				N
10: Is repeated/sustained work performed with neck:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				

d) extended backwards?	N				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	Y				Y
b) weight of load	Y				Y
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	Y				Y
f) handling below knee length	Y				Y
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	19	9	4	4	15
PERCENTAGE	73.1	81.8	50	50	71.4

Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores	
18: Is there no possibility to take breaks and pauses?	N

19: Is there no possibility to choose order and type of work tasks or pace of work?	N
20: Is the job performed under time demands or psychological stress?	N
21:Can the work have unusual or expected situations?	N
22: Are the following present?	
a) cold	Y
b) heat	Y
c) draft	Y
d) noise	Y
e) troublesome visual conditions	N
f) jerks, shakes, or vibration	N
Environmental / Organizational Risk Factors Score	
SUM	4
PERCENTAGE	40.0

Table 18. Cable Pull (3/4 inch diameter) RULA

Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

Date/ Time	***Facility***	***Area/Shop***	***Task***
4/17/00		*Shipboard*	Cable Pulling (3/4")

RULA: Posture Sampling Results

RULA Component	**Frames # 115920-116820 Pull cable**		**Frame # 128130 Feed cable**		**Frame # 134490 Change position**		**Frame # 133770 Adjusting cable**		**Frame # 22409 Tie cables**		**Frame # 130170 Rest**	
	Spec	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*
Shoulder Extension/ Flexion	**mod flex**	**3**	**hyp flex**	**4**	**mod flex**	**3**	**hyp flex**	**4**	**hyp flex**	**4**	**neut**	**1**
Shoulder is Raised (+1)		**0**		**1**		**0**		**1**		**1**		**0**
Upper Arm Abducted (+1)		**1**		**0**		**0**		**0**		**0**		**0**
Arm supported, leaning (-1)		**0**		**0**		**0**		**0**		**0**		**0**
Elbow Extension/ Flexion	**neut**	**2**	**ext**	**1**	**neut**	**2**	**ext**	**1**	**ext**	**1**	**ext**	**1**
Shoulder Abduction/ Adduction	**mod abd**	**1**	**neut**	**0**	**neut**	**0**	**neut**	**0**	**neut**	**0**	**neut**	**0**
Shoulder Lateral/ Medial	**lat**	**1**	**mod med**	**1**	**neut**	**0**	**neut**	**0**	**neut**	**0**	**neut**	**0**
Wrist Extension/ Flexion	**ext**	**2**	**neut**	**1**	**neut**	**1**	**ext**	**2**	**ext**	**2**	**neut**	**1**
Wrist Deviation	**ulnar**	**1**	**ulnar**	**1**	**neut**	**0**	**ulnar**	**1**	**ulnar**	**1**	**neut**	**0**
Wrist Bent from Midline (+1)		**0**		**0**		**0**		**0**		**0**		**0**
Wrist Twist (1) In mid range or (2) End of range		**1**		**1**		**1**		**1**		**1**		**1**
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		**0**		**0**		**0**		**0**		**0**		**0**
Arm and Wrist Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		**3**		**2**		**1**		**1**		**1**		**0**

Table 18. Cable Pull (3/4 inch diameter) RULA (continued)

RULA Component	Frames # 115920-116820 Pull cable		Frame # 128130 Feed cable		Frame # 134490 Change position		Frame # 22080 Adjusting cable		Frame # 22409 Tie cables		Frame # 18000 Rest	
	Spec	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*
Neck Extension/ Flexion	neut	1	ext	4	ext	4	ext	4	ext	4	sl flx	2
Neck Twist (+1)		1		1		1		0		0		0
Neck Side-Bent (+1)		0		0		0		0		0		0
Trunk Extension/ Flexion	neut	1	neut	1	neut	1	neut	1	neut	1	neut	1
Trunk Twist (+1)		1		1		1		0		0		0
Trunk Side Bend (+1)		0		0		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		0		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		3		2		1		1		1		0
Total RULA Score	7		7		3		5		5		1	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 19. Cable Pullers (3/4 inch diameter) Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
Moore and Garg, 1995

Date/ Time	Facility	Area/Shop	Task
4/17/00		Shipboard	Cable Pull 3/4"

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	% MS *(percentage of maximal strength)*	Borg Scale *(Compare to Borg Cr-10 Scale)*	Perceived Effort	Rating	Multiplier
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**6.0**

Table 19. Cable Pullers (3/4 inch diameter) Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: % Duration of Exertion = 100 x duration of all exertions (sec) / Total observation time (sec) = 100 x 330(sec)/ 745 (sec) = 44	**Rating Criterion**	**Rating**	**Multiplier**
	< 10	1	0.5
	10 - 29	2	1.0
	30 - 49	3	1.5
	50 -79	4	2.0
	> or = 80	5	3.0
Duration of Exertion Multiplier			**1.5**
3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: Efforts per Minute = number of exertions / total observation time (min) = 20/ 12.45 = 1.6	**Rating Criterion**	**Rating**	**Multiplier**
	< 4	1	0.5
	4 - 8	2	1.0
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			**0.5**

Table 19. Cable Pullers (3/4 inch diameter) Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	**Wrist Extension** *(Stetson et al, 1991)*	**Wrist Flexion** *(Stetson et al, 1991)*	**Ulnar Deviation** *(Stetson et al, 1991)*	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral (*estimated, based on RULAs performed)	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.5**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	**Compared to MTM** *(observed pace is divided by MTM's predicted pace and expressed as %)*	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	91 -100%	"normal" speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 19. Cable Pullers (3/4 inch diameter) Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet: Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate @4-8 hrs)	***Rating Criterion***	***Rating***	***Multiplier***
	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**1.00**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**	**=**	**SI SCORE**
6.0 X	**1.5 X**	**0.5 X**	**1.5 X**	**1.0 X**	**1.0**		**6.8**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 20. Cable Pullers (3/4 inch diameter) UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders

Lifshitz and Armstrong (1986)

Date/ Time	Facility	Area/Shop	Task
4/17/00		Shipboard	Cable Pull 3/4"

* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	No	Yes
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?	N	
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	n/a	n/a
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	n/a	n/a
6.3 Is the handle of the tool made from material other than metal?	n/a	n/a

6.4 Is the weight of the tool below 4 kg (9lbs)?	n/a	n/a
6.5 Is the tool suspended?	n/a	n/a
TOTAL	**14 (74%)**	**5 (26%)**

Table 21. Cable Pullers (3/4 inch diameter) OWAS

OWAS: OVAKO Work Analysis System

Louhevaara and Suurnäkki (1992)

Procedure: Observe workers at intervals of 30-60 seconds. Record postures and forces over a representative period (~ 45 minutes)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00		Shipboard	Cable Pulling (3/4")

Risk Factor	**Work Phase1** **Pull cable**	**Work Phase 2** **Feed cable**	**Work Phase 3** **Change position**	**Work Phase 4** **Adjust cable**	**Work Phase 5** **Tie cables**	**Work Phase 6** **Rest**
TOTAL Combination Posture Score	**1**	**1**	**1**	**1**	**2**	**1**
Common Posture Combinations (collapsed across work phases)						
Back	1	1	1	2		
Arms	1	2	3	3		
Legs	2	2	2	2		
Posture Repetition (% of working time)	12	24	9	5		
BACK % of Working Time SCORE	**1**	**1**	**1**	**1**		
ARMS % of Working Time SCORE	**1**	**1**	**1**	**1**		
LEGS % of Working Time SCORE	**1**	**1**	**1**	**1**		

ACTION CATEGORIES:

1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Table 21. Cable Pullers (3/4 inch diameter) OWAS (continued)

Risk Factor	Work Phase1 Pull cable	Work Phase 2 Feed cable	Work Phase 3 Change position	Work Phase 4 Adjust cable	Work Phase 5 Tie cables	Work Phase 6 Rest
Posture						
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	1	1	1	1	2	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	2	2	3	3	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	2	2	2	2	2	2
Load/ Use of Force						
1 = weight or force needed is = or <10 kg (<22lbs) 2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs) 3 = weight or force > 20 kg (>44 lbs)	2	2	1	1	1	1
Phase Repetition						
% of working time (0,10,20,30,40,50,60,70,80,90,100)	4	16	8	9	5	8

Table 22. Cable Pullers (3/4 inch diameter) PLIBEL

PLIBEL Checklist, Kemmlert (1995)

Date/ Time	Facility	Area/Shop	Task
4/17/00		Shipboard	Cable Pull 3/4"

Section I: Musculoskeletal Risk Factors **Methods of Application:** **1) Find the injured body region, answer yes or no to corresponding questions** **2) Answer questions, score potential body regions for injury risk**					
Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	Y	Y	Y	Y	Y
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			Y	Y	Y
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward? **backwards in this case	Y				Y
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N
10: Is repeated/sustained work performed with neck:					
a) flexed forward?	N				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				

d) extended backwards?	Y				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	Y				Y
f) handling below knee length	N				N
g) handling above shoulder height	Y				Y
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	15	9	4	4	11
PERCENTAGE	57.7	81.8	50	50	52.4

Section II: Environmental / Organizational Risk Factors (Modifying) **Answer below questions, use to modify interpretation of musculoskeletal scores**	
18: Is there no possibility to take breaks and pauses?	N

19: Is there no possibility to choose order and type of work tasks or pace of work?	N
20: Is the job performed under time demands or psychological stress?	N
21:Can the work have unusual or expected situations?	N
22: Are the following present?	
a) cold	Y
b) heat	Y
c) draft	Y
d) noise	Y
e) troublesome visual conditions	N
f) jerks, shakes, or vibration	N
Environmental / Organizational Risk Factors Score	
SUM	4
PERCENTAGE	40.0

E10.4 Table 23. Equipment Loaders RULA

Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00		Shipboard	Equipment Load In

RULA Component	**Frame # 50490 Lower equipment through hatch**		**Frame # 10110 Roll equipment on low profile cart**		**Frame # 12990 Slide equipment**		**Frame # 22080 Roll equipment on rollers**		**Frame # 22409 Tilt equipment**		**Frame # 18000 Waiting for new load to be delivered**	
	Specific	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*
Shoulder Extension/ Flexion	sl flex	2	sl flex	2	mod flex	3	mod flex	3	sl flex	2	neut	1
Shoulder is Raised (+1)		0		0		1		1		1		0
Upper Arm Abducted (+1)		0		0		0		1		0		0
Arm supported, leaning (-1)		0		0		0		0		0		0
Elbow Extension/ Flexion	neut	2	neut	2	ext	1	neut	2	flx	2	ext	1
Shoulder Abduction/ Adduction	neut	0	neut	0	mod abd	1	mod abd	1	mod abd	1	neut	0
Shoulder Lateral/ Medial	neut	0	neut	0	mod med	1	mod med	1	mod med	1	neut	0
Wrist Extension/ Flexion	ext	2	neut	1	ext	2	flx	2	ext	2	neut	1
Wrist Deviation	neut	0	neut	0	neut	0	neut	0	neut	0	neut	0
Wrist Bent from Midline (+1)		0		0		0		0		0		0
Wrist Twist (1) In mid range **Or** (2) End of range		1		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		0		0		0
Arm and Wrist Force/ load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		2		3		3		3		0

Table 23. Equipment Loaders RULA (continued)

RULA Component	**Frame # 50490 Lower equipment through hatch**		**Frame # 10110 Roll equipment on low profile cart**		**Frame # 12990 Slide equipment**		**Frame # 22080 Roll equipment on rollers**		**Frame # 22409 Tilt equipment**		**Frame # 18000 Waiting for new load to be delivered**	
	Specific	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*
Neck Extension/ Flexion		1		2		1		2		2		1
Neck Twist (+1)		0		0		0		0		0		0
Neck Side-Bent (+1)		0		0		0		0		0		0
Trunk Extension/ Flexion	neut	1	sl flx	2	sl flx	2	sl flx	2	sl flx	2	neut	1
Trunk Twist (+1)		0		0		0		1		1		0
Trunk Side Bend (+1)		0		0		0		1		1		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		0		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		2		3		3		3		0
Total Rula Score	3		4		6		7		7		1	

1 or 2 = ACCEPTABLE
3 or 4 = INVESTIGATE FURTHER
5 or 6 = INVESTIGATE FURTHER AND CHANGE SOON
7 = INVESTIGATE AND CHANGE IMMEDIATELY

Table 24. Equipment Loaders Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
Moore and Garg, 1995

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00		Shipboard	Equipment Load In

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.					
Rating Criterion	**% MS** *(percentage of maximal strength)*	**Borg Scale** *(Compare to Borg Cr-10 Scale)*	**Perceived Effort**	**Ratin g**	**Multiplie r**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewh at hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**6.0**

Table 24. Equipment Loaders Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: % Duration of Exertion = 100 x duration of all exertions (sec) Total observation time (sec) = 100 x 1495(sec)/ 2910 (sec) = 51	**Rating Criterion**	**Rating**	**Multiplier**
	< 10	1	0.5
	10 - 29	2	1.0
	30 - 49	3	1.5
	50 -79	4	2.0
	> or = 80	5	3.0
Duration of Exertion Multiplier			**2.0**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: Efforts per Minute = number of exertions total observation time (min) = 108/ 48 min = 2.2	**Rating Criterion**	**Rating**	**Multiplier**
	< 4	1	0.5
	4 - 8	2	1.0
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			**0.5**

Table 24. Equipment Loaders Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	**Wrist Extension** *(Stetson et al, 1991)*	**Wrist Flexion** *(Stetson et al, 1991)*	**Ulnar Deviation** *(Stetson et al, 1991)*	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral (*estimated, based on RULAs performed)	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.0**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	**Compared to MTM** *(observed pace is divided by MTM's predicted pace and expressed as %)*	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	91 -100%	"normal" speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 24. Equipment Loaders Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet: Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate @ 2-4 hrs)	***Rating Criterion***	***Rating***	***Multiplier***
	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**0.75**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duratio n of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duratio n of Task**		**SI SCORE**
6.0 X	**2.0 X**	**0.5 X**	**1.0 X**	**1.0 X**	**0.75**	**=**	**4.5**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:

- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 25. Equipment Loaders UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders Lifshitz and Armstrong (1986)

Date/ Time	Facility	Area/Shop	Task
4/17/00		Shipboard	Equipment Load In

* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	No	Yes
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?		Y
3.4 Can the tool be used without deviating the wrist from side to side?		Y
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	n/a	n/a
4.2 Can the height of the work surface be adjusted?	n/a	n/a
4.3 Can the location of the tool be adjusted?	n/a	n/a
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?		Y
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	n/a	n/a
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	n/a	n/a
6.3 Is the handle of the tool made from material other than metal?	n/a	n/a
6.4 Is the weight of the tool below 4 kg (9lbs)?	n/a	n/a
6.5 Is the tool suspended?	n/a	n/a
TOTAL	**8 (50%)**	**8 (50%)**

Table 26. Equipment Loaders OWAS

OWAS: OVAKO Work Analysis System
Louhevaara and Suurnäkki (1992)

Procedure: Observe workers at intervals of 30-60 seconds. Record postures and forces over a representative period (~ 45 minutes)

Date/ Time	Facility	Area/Shop	Task
4/17/00		Shipboard	Equipment Load In

Risk Factor	Work Phase1 Lower equipment through hatch	Work Phase 2 Roll equip-ment on low profile cart	Work Phase 3 Slide equip-ment	Work Phase 4 Roll equipment on rollers	Work Phase 5 Tilt equip-ment	Work Phase 6 Waiting for new load to be de-livered
TOTAL Combination Posture Score	**1**	**3**	**3**	**3**	**2**	**1**
Common Posture Combinations (collapsed across work phases)						
Back	1	2	2			
Arms	1	1	1			
Legs	2	7	6			
Posture Repetition (% of working time)	58	18	11			
BACK % of Working Time SCORE	**1**	**1**	**1**	**1**		
ARMS % of Working Time SCORE	**1**	**1**	**1**	**1**		
LEGS % of Working Time SCORE	**1**	**1**	**1**	**1**		

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Table 26. Equipment Loaders OWAS (continued)

Risk Factor	Work Phase1 Lower equipment through hatch	Work Phase 2 Roll equip-ment on low profile cart	Work Phase 3 Slide equip-ment	Work Phase 4 Roll equipment on rollers	Work Phase 5 Tilt equip-ment	Work Phase 6 Waiting for new load to be de-livered
Posture						
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	1	2	2	2	2	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	2	7	7	7	6	2
Load/ Use of Force						
1 = weight or force needed is = or <10 kg (<22lbs) 2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs) 3 = weight or force > 20 kg (>44 lbs)	1	2	3	3	3	1
Phase Repetition						
% of working time (0,10,20,30,40,50,60,70,80,90,100)	12	4	7	7	11	46

Table 27. Equipment Loaders PLIBEL

PLIBEL Checklist, Kemmlert (1995)

Date/ Time	Facility	Area/Shop	Task
4/17/00		Shipboard	Equipment Load In

Section I: Musculoskeletal Risk Factors
Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	Y	Y	Y	Y	Y
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	n/a				n/a
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N
10: Is repeated/sustained work performed with neck:					
a) flexed forward?	N				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				

d) extended backwards?	N				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	Y				Y
b) weight of load	Y				Y
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	Y				Y
e) handling beyond forearm length	Y				Y
f) handling below knee length	Y				Y
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	N				
14: Is there a repetition of:					
a) similar work movements?	N	N			
b) similar work movements beyond comfortable reaching distance?	N	N			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 27. Equipment Loaders PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	13	7	3	3	12
PERCENTAGE	50	63.6	37.5	37.5	57.1

Section II: Environmental / Organizational Risk Factors (Modifying) **Answer below questions, use to modify interpretation of musculoskeletal scores**	
18: Is there no possibility to take breaks and pauses?	N
19: Is there no possibility to choose order and type of work tasks or pace of work?	N
20: Is the job performed under time demands or psychological stress?	N
21:Can the work have unusual or expected situations?	N
22: Are the following present?	
a) cold	Y
b) heat	Y
c) draft	Y
d) noise	Y
e) troublesome visual conditions	N
f) jerks, shakes, or vibration	N
Environmental / Organizational Risk Factors Score	
SUM	4
PERCENTAGE	40.0

Table 28. Shipboard Rigger (Equipment Load-In) 3D Static Strength Prediction Program

3D Static Strength Prediction Program

(University of Michigan, 1997)

Date/ Time	Facility	Area/Shop	Task
4/17/00		Shipboard	Equipment load in

Work Elements: Shipboard Rigger Tilting Equipment Frame Components	Disc Compression (lbs) @ L5/S1 (Note: NIOSH Recommended Compression Limit (RCL) is 770 lbs)
Shipboard Rigger tilts equipment: approximate hand loads of 100 pounds	789 pounds

E10.5. Table 29. Insulation Cutters RULA

Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

Date/ Time	***Facility***	***Area/Shop***	***Task***
4/17/99		*Shipboard*	*Insulation Cutters*

RULA: Posture Sampling Results

RULA Component	**Frame # 150000 Measure/ mark**		**Frame # 170220 Change tool**		**Frame # 170490 Cut**		**Frame # 130920 Pass to installer**		**Frame # 128880 Move insulation**	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Shoulder Extension/ Flexion	sl flex	2	neut	1	sl flex	2	sl flex	2	sl flex	2
Shoulder is Raised (+1)		0		0		1		0		0
Upper Arm Abducted (+1)		0		0		1		0		1
Arm supported, leaning (-1)		-1		0		0		0		0
Elbow Extension/ Flexion	ext	1	ext	1	neut	2	ext	1	ext	1
Shoulder Abduction/ Adduction	neut	0	neut	0	mod abd	1	neut	0	mod abd	1
Shoulder Lateral/ Medial	neut	0	neut	0	lat	1	neut	0	lat	1
Wrist Extension/ Flexion	neut	1	neut	1	flx	2	neut	1	neut	1
Wrist Deviation	neut	0	neut	0	ulnar	1	neut	0	neut	0
Wrist Bent from Midline (+1)		0		0		0		0		0
Wrist Twist (1) In mid range or (2) End of range		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		0		0
Arm and Wrist Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		0		0		1		0		0

Table 29. Insulation Cutters RULA (continued)

RULA Component	Frame # 150000 Measure/ mark		Frame # 170220 Change tool		Frame # 170490 Cut		Frame # 130920 Pass to installer		Frame # 128880 Move insulation	
	Spec	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*
Neck Extension/ Flexion	sl flx	2	neut	1	mod flx	3	neut	1	neut	1
Neck Twist (+1)		0		0		0		0		0
Neck Side-Bent (+1)		0		0		0		0		0
Trunk Extension/ Flexion	sl flx	2	neut	1	neut	1	neut	1	neut	1
Trunk Twist (+1)		0		0		0		0		0
Trunk Side Bend (+1)		0		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		1		1		1		1
Total RULA Score	**3**		**2**		**5**		**2**		**2**	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 30. Insulation Cutters Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
Moore and Garg, 1995

Date/ Time	Facility	Area/Shop	Task
4/17/00		Shipboard	Insulation cutter

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**% MS** *(percentage of maximal strength)*	**Borg Scale** *(Compare to Borg Cr-10 Scale)*	**Perceived Effort**	**Rating**	**Multiplier**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**1.0**

Table 30. Insulation Cutters Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: % Duration of Exertion = 100 x duration of all exertions (sec) Total observation time (sec) = 100 x 920(sec)/ 2255 (sec) = 41	**Rating Criterion**	**Rating**	**Multiplier**
	< 10	1	0.5
	10 - 29	2	1.0
	30 - 49	3	1.5
	50 -79	4	2.0
	> or = 80	5	3.0
Duration of Exertion Multiplier			**1.5**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: Efforts per Minute = number of exertions total observation time (min) = 89/38 = 2.4	**Rating Criterion**	**Rating**	**Multiplier**
	< 4	1	0.5
	4 - 8	2	1.0
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			**0.5**

Table 30. Insulation Cutters Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	**Wrist Extension** *(Stetson et al, 1991)*	**Wrist Flexion** *(Stetson et al, 1991)*	**Ulnar Deviation** *(Stetson et al, 1991)*	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral (*estimated, based on RULAs performed)	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.5**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	**Compared to MTM** *(observed pace is divided by MTM's predicted pace and expressed as %)*	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	91 -100%	"normal" speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 30 . Insulation Cutters Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet: Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate @4-8 hrs)	***Rating Criterion***	***Rating***	***Multiplier***
	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**1.00**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**		**SI SCORE**
1.0 X	**1.5 X**	**0.5 X**	**1.5 X**	**1.0 X**	**1.0**	**=**	**1.1**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 31. Insulation Cutters UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders

Lifshitz and Armstrong (1986)

Date/ Time	Facility	Area/Shop	Task
4/17/00		Shipboard	Insulation Cutter

* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	No	Yes
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?		Y
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?		Y
2.2 Can the job be done without using finger pinch grip?	N	
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	N	
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	N	
6.3 Is the handle of the tool made from material other than metal?		Y

6.4 Is the weight of the tool below 4 kg (9lbs)?		Y
6.5 Is the tool suspended?	N	
TOTAL	**14 (64%)**	**8 (36%)**

Table 32. Insulation Cutters OWAS

OWAS: OVAKO Work Analysis System
Louhevaara and Suurnäkki (1992)

Procedure: Observe workers at intervals of 30-60 seconds. Record postures and forces over a representative period (~ 45 minutes)

Date/ Time	Facility	Area/Shop	Task
4/17/99		Shipboard	Insulation cutter

Risk Factor	Work Phase1 Measure / mark	Work Phase 2 Change tool	Work Phase 3 Cut	Work Phase 4 Pass to installer	Work Phase 5 Move insulation
TOTAL Combination Posture Score	**1**	**1**	**2**	**1**	**1**
Common Posture Combinations (collapsed across work phases)					
Back	1	2			
Arms	1	2			
Legs	2	2			
Posture Repetition (% of working time)	26	14			
BACK % of Working Time SCORE	**1**	**1**			
ARMS % of Working Time SCORE	**1**	**1**			
LEGS % of Working Time SCORE	**1**	**1**			

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Table 32. Insulation Cutters OWAS (continued)

Risk Factor	Work Phase1 Measure / mark	Work Phase 2 Change tool	Work Phase 3 Cut	Work Phase 4 Pass to installer	Work Phase 5 Move insulation
Posture					
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	1	1	2	1	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	2	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	2	2	2	2	2
Load/ Use of Force					
1 = weight or force needed is = or <10 kg (<22lbs)	1	1	1	1	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)					
3 = weight or force > 20 kg (>44 lbs)					
Phase Repetition					
% of working time (0,10,20,30,40,50,60,70,80,90,100)	20	3	14	1	2

Table 33. Insulation Cutters PLIBEL

PLIBEL Checklist, Kemmlert (1995)

Date/ Time	Facility	Area/Shop	Task
4/17/00		Shipboard	Insulation cutter

Section I: Musculoskeletal Risk Factors
Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			N	N	N
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	N				N
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			Y	Y	Y
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N
10: Is repeated/sustained work performed with neck:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				

d) extended backwards?	N				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	N				N
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	N				N
f) handling below knee length	N				N
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	N	N			N
13: Is sustained work performed when one arm reaches forward or to the side without support?	N				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	N	N			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	N	N			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			
Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	6	5	2	2	4
PERCENTAGE	23.1	45.5	25	25	19
Section II: Environmental / Organizational Risk Factors (Modifying) **Answer below questions, use to modify interpretation of musculoskeletal scores**					
18: Is there no possibility to take breaks and pauses?	N				

19: Is there no possibility to choose order and type of work tasks or pace of work?	N
20: Is the job performed under time demands or psychological stress?	N
21:Can the work have unusual or expected situations?	N
22: Are the following present?	
a) cold	Y
b) heat	Y
c) draft	Y
d) noise	Y
e) troublesome visual conditions	N
f) jerks, shakes, or vibration	N
Environmental / Organizational Risk Factors Score	
SUM	4
PERCENTAGE	40.0

Table 34. Insulation Installers RULA

Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

Date/ Time	*Facility*	*Area/Shop*	*Task*
4/17/99		*Shipboard*	*Insulation Installers*

RULA: Posture Sampling Results

RULA Component	**Frame # 169050 Wait for cutter, rest**		**Frame # 131100 Place insulation overhead**		**Frame # 152580 Measure, relay info to cutter**		**Frame # 137820 Repo-sition body, ladder**		**Frame # 156840 Trim insulation, cut tie holes**		**Frame # 157680 Install, hammer ties**	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Shoulder Extension/ Flexion	neut	1	hyp flex	4	hyp flex	4	sl flex	2	hyp flex	4	hyp flex	4
Shoulder is Raised (+1)		0		1		1		0		1		1
Upper Arm Abducted (+1)		0		0		0		0		0		0
Arm supported, leaning (-1)		0		0		0		0		0		0
Elbow Extension/ Flexion	neut	2	ext	1	ext	1	ext	1	ext	1	ext	1
Shoulder Abduction/ Adduction	neut	0	neut	0	neut	0	add	1	neut	0	neut	0
Shoulder Lateral/ Medial	neut	0	mod med	1	mod med	1	neut	0	neut	0	neut	0
Wrist Extension/ Flexion	neut	1	ext	2	neut	1	neut	1	ext	2	ext	2
Wrist Deviation	neut	0	ulnar	1	neut	0	neut	0	ulnar	1	ulnar	1
Wrist Bent from Midline (+1)		0		0		0		0		0		0
Wrist Twist (1) In mid range or (2) End of range		1		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		0		0		0
Arm and Wrist Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		0		1		1		1		1		1

Table 34. Insulation Installers RULA (continued)

RULA Component	Frame # 169050 Wait for cutter, rest		Frame # 131100 Place insulation overhead		Frame # 152580 Measure, relay info to cutter		Frame # 137820 Repo-sition body, ladder		Frame # 156840 Trim insulation, cut tie holes		Frame # 157680 Install, hammer ties	
	Spec	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*	*Spec*	*RULA Score*
Neck Extension/ Flexion	neut	1	ext	4	ext	4	sl flx	2	ext	4	ext	4
Neck Twist (+1)		0		0		0		0		0		0
Neck Side-Bent (+1)		0		0		0		0		0		0
Trunk Extension/ Flexion	neut	1	neut	1	neut	1	neut	1	neut	1	neut	1
Trunk Twist (+1)		0		0		0		0		0		0
Trunk Side Bend (+1)		0		0		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		0		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		1		1		1		1		1
Total RULA Score	**2**		**6**		**5**		**3**		**5**		**5**	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 35. Insulation Installers Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
Moore and Garg, 1995

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00		Shipboard	Insulation Installers

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**% MS** *(percentage of maximal strength)*	**Borg Scale** *(Compare to Borg Cr-10 Scale)*	**Perceived Effort**	**Ratin g**	**Multiplie r**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewh at hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**3.0**

Table 35. Insulation Installers Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: % Duration of Exertion = 100 x duration of all exertions (sec) / Total observation time (sec) = 100 x 1466(sec)/ 2255 (sec) = 65	**Rating Criterion**	**Rating**	**Multiplier**
	< 10	1	0.5
	10 - 29	2	1.0
	30 - 49	3	1.5
	50 -79	4	2.0
	> or = 80	5	3.0
Duration of Exertion Multiplier			**2.0**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: Efforts per Minute = number of exertions / total observation time (min) = 76/38 = 2**, but rather static so set multiplier to 1.0**	**Rating Criterion**	**Rating**	**Multiplier**
	< 4	1	0.5
	4 - 8	2	1.0
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			**1.0**

Table 35. Insulation Installers Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	**Wrist Extension** *(Stetson et al, 1991)*	**Wrist Flexion** *(Stetson et al, 1991)*	**Ulnar Deviation** *(Stetson et al, 1991)*	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation (*estimated, based on RULAs performed)	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**2.0**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	**Compared to MTM** *(observed pace is divided by MTM's predicted pace and expressed as %)*	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	91 -100%	"normal" speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 35. Insulation Installers Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet: Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate @4-8 hrs)	***Rating Criterion***	***Rating***	***Multiplier***
	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**1.00**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**		**SI SCORE**
3.0 X	**2.0 X**	**1.0 X**	**2.0 X**	**1.0 X**	**1.0**	**=**	**12**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:

- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 36. Insulation Installers UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders

Lifshitz and Armstrong (1986)

Date/ Time	Facility	Area/Shop	Task
4/17/00		Shipboard	Insulation Installer

* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	No	Yes
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?		Y
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?	N	
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	N	
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	N	
6.3 Is the handle of the tool made from material other than metal?		Y

6.4 Is the weight of the tool below 4 kg (9lbs)?		Y
6.5 Is the tool suspended?	N	
TOTAL	**15 (68%)**	**7 (32%)**

Table 37. Insulation Installers OWAS

OWAS: OVAKO Work Analysis System
Louhevaara and Suurnäkki (1992)

Procedure: Observe workers at intervals of 30-60 seconds. Record postures and forces over a representative period (~ 45 minutes)

Date/ Time	Facility	Area/Shop	Task
4/17/99		Shipboard	Insulation Installing

Risk Factor	Work Phase1 Wait for cutter, rest	Work Phase 2 Place insulation overhead	Work Phase 3 Measure, relay info to cutter	Work Phase 4 Repo-sition body, ladder	Work Phase 5 Trim insulation and cut tie holes	Work Phase 6 Install, hammer ties
TOTAL Combination Posture Score	**1**	**2**	**2**	**1**	**2**	**2**
Common Posture Combinations (collapsed across work phases)						
Back	1	2				
Arms	1	3				
Legs	2	2				
Posture Repetition (% of working time)	39	55				
BACK % of Working Time SCORE	**1**	**2**				
ARMS % of Working Time SCORE	**1**	**2**				
LEGS % of Working Time SCORE	**1**	**1**				

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Table 37. Insulation Installers OWAS (continued)

Risk Factor	*Work Phase1* *Wait for cutter, rest*	*Work Phase 2* *Place insulation overhead*	*Work Phase 3* *Measure, relay info to cutter*	*Work Phase 4* *Repo-sition body, ladder*	*Work Phase 5* *Trim insulation and cut tie holes*	*Work Phase 6* *Install, hammer ties*
Posture						
Back *1 = straight* *2 = bent forward, backward* *3 = twisted or bent sideways* *4 = bent and twisted or bent forward and sideways*	*1*	*2*	*2*	*1*	*2*	*2*
Arms *1 = both arms are below shoulder level* *2 = one arm is at or above shoulder level* *3 = both arms are at or above shoulder level*	*1*	*3*	*3*	*1*	*3*	*3*
Legs *1 = sitting* *2 = standing with both legs straight* *3 = standing with the weight on one straight leg* *4 = standing or squatting with both knees bent* *5 = standing or squatting with one knee bent* *6 = kneeling on one or both knees* *7 = walking or moving*	*2*	*2*	*2*	*2*	*2*	*2*
Load/ Use of Force						
1 = weight or force needed is = or <10 kg (<22lbs) *2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)* *3 = weight or force > 20 kg (>44 lbs)*	*1*	*1*	*1*	*1*	*1*	*1*
Phase Repetition						
% of working time (0,10,20,30,40,50,60,70,80,90,100)	*32*	*14*	*20*	*7*	*9*	*12*

Table 38. Insulation Installers PLIBEL

PLIBEL Checklist, Kemmlert (1995)

Date/ Time	Facility	Area/Shop	Task
4/17/00		Shipboard	Insulation Installers

Section I: Musculoskeletal Risk Factors
Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	Y	Y	Y	Y	Y
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			Y	Y	Y
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			Y	Y	Y
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N
10: Is repeated/sustained work performed with neck:					
a) flexed forward?	N				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	Y				

11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	Y				Y
e) handling beyond forearm length	N				N
f) handling below knee length	N				N
g) handling above shoulder height	Y				Y
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	N	N			N
13: Is sustained work performed when one arm reaches forward or to the side without support?	N				
14: Is there a repetition of:					
a) similar work movements?	N	N			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	N	N			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		N			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	13	5	5	5	12
PERCENTAGE	50	45.5	62.5	62.5	57.1

Section II: Environmental / Organizational Risk Factors (Modifying)
Answer below questions, use to modify interpretation of musculoskeletal scores

18: Is there no possibility to take breaks and pauses?	N

19: Is there no possibility to choose order and type of work tasks or pace of work?	N
20: Is the job performed under time demands or psychological stress?	N
21:Can the work have unusual or expected situations?	N
22: Are the following present?	
a) cold	Y
b) heat	Y
c) draft	Y
d) noise	Y
e) troublesome visual conditions	N
f) jerks, shakes, or vibration	N
Environmental / Organizational Risk Factors Score	
SUM	4
PERCENTAGE	40.0

E10.6 Table 39. Panel line wire welders RULA

Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

Date/ Time	***Facility***	***Area/Shop***	***Task***
7/26/99		*Shipboard*	*Panel Line Wire Welding*

RULA: Posture Sampling Results

RULA Component	**Frame # 72270 Inspect**		**Frame # 74010 Grinding crouched /kneeling**		**Frame # 85290 Change tool**		**Frame # 87120 Wire weld kneeling**		**Frame # 96240 Re-arrange equip-ment**		**Frame # 92220 Change position**	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Shoulder Extension/ Flexion	mod flex	3	mod flex	3	neut	1	mod flex	3	sl flex	2	sl flex	2
Shoulder is Raised (+1)		0		0		0		0		0		0
Upper Arm Abducted (+1)		0		0		0		0		0		0
Arm supported, leaning (-1)		-1		0		0		-1		-1		0
Elbow Extension/ Flexion	neut	2	ext	1	ext	1	neut	2	ext	1	neut	2
Shoulder Abduction/ Adduction	neut	0	add	1	neut	0	add	1	neut	0	neut	0
Shoulder Lateral/ Medial	neut	0	mod med	1	neut	0	mod med	1	neut	0	neut	0
Wrist Extension/ Flexion	neut	1	ext	2	neut	1	ext	2	neut	1	neut	1
Wrist Deviation	neut	0	ulnar	1	neut	0	ulnar	1	neut	0	neut	0
Wrist Bent from Midline (+1)		0		0		0		0		0		0
Wrist Twist (1) In mid range or (2) End of range		1		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		1		0		0
Arm and Wrist Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		0		1		1		2		1		1

Table 39. Panel line wire welders RULA (continued)

RULA Component	**Frame # 72270 Inspect**		**Frame # 74010 Grinding crouched /kneeling**		**Frame # 85290 Change tool**		**Frame # 87120 Wire weld kneeling**		**Frame # 96240 Re-arrange equip-ment**		**Frame # 92220 Change position**	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Neck Extension/ Flexion	extr flx	3	extr flx	3	sl flx	2	ext	4	ext	4	ext	4
Neck Twist (+1)		0		0		0		0		0		0
Neck Side-Bent (+1)		0		0		0		0		0		0
Trunk Extension/ Flexion	mod flx	3	mod flx	3	neut	1	extr flx	4	mod flx	3	mod flx	3
Trunk Twist (+1)		0		0		0		0		0		0
Trunk Side Bend (+1)		0		0		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		1		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		1		1		2		1		1
Total RULA Score	**3**		**5**		**2**		**7**		**3**		**3**	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 40. Panel Line Welders Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
Moore and Garg, 1995

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00		Panel line	Panel Line Wire Welding

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**% MS** *(percentage of maximal strength)*	**Borg Scale** *(Compare to Borg Cr-10 Scale)*	**Perceived Effort**	**Rating**	**Multiplier**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**3.0**

Table 40. Panel Line Welders Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: % Duration of Exertion = 100 x duration of all exertions (sec) Total observation time (sec) = 100 x 720(sec)/ 1321 (sec) = 54	**Rating Criterion**	**Rating**	**Multiplier**
	< 10	1	0.5
	10 - 29	2	1.0
	30 - 49	3	1.5
	50 -79	4	2.0
	> or = 80	5	3.0
Duration of Exertion Multiplier			**2.0**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: Efforts per Minute = number of exertions total observation time (min) = nearly static exertion, therefore **multiplier = 3**	**Rating Criterion**	**Rating**	**Multiplier**
	< 4	1	0.5
	4 - 8	2	1.0
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			**3.0**

Table 40. Panel Line Welders Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	**Wrist Extension** *(Stetson et al, 1991)*	**Wrist Flexion** *(Stetson et al, 1991)*	**Ulnar Deviation** *(Stetson et al, 1991)*	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral (*estimated, based on RULAs performed)	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.5**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	**Compared to MTM** *(observed pace is divided by MTM's predicted pace and expressed as %)*	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	91 -100%	"normal" speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 40. Panel Line Welders Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet: Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate @4-8 hrs)	***Rating Criterion***	***Rating***	***Multiplier***
	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**1.00**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**	**____=**	**SI SCORE**
3.0 X	**2.0 X**	**3.0 X**	**1.5 X**	**1.0 X**	**1.0**		**27**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 41. Panel Line Welders UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders

Lifshitz and Armstrong (1986)

Date/ Time	Facility	Area/Shop	Task
4/17/00		Shipboard	Panel Line Wire Welding

* “No” responses are indicative of conditions associated with the risk of CTD’s

Risk Factors	No	Yes
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker’s hands exposed to temperature >21degrees C (70 degrees F)?		Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without “clothes wringing” motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?		Y
6.2 Is the span of the tool’s handle between 5 and 7 cm (2-2 3/4 inches)?		Y (welding)
6.3 Is the handle of the tool made from material other than metal?		Y

6.4 Is the weight of the tool below 4 kg (9lbs)?		Y
6.5 Is the tool suspended?	N	
TOTAL	**12 (57%)**	**9 (43%)**

Table 42. Panel line welders OWAS

OWAS: OVAKO Work Analysis System
Louhevaara and Suurnäkki (1992)

Procedure: Observe workers at intervals of 30-60 seconds. Record postures and forces over a representative period (~ 45 minutes)

Date/ Time	Facility	Area/Shop	Task
4/17/00		Shipboard	Panel Line Wire Welding

Risk Factor	Work Phase1 Inspect	Work Phase 2 Grinding crouched/ kneeling	Work Phase 3 Change tool	Work Phase 4 Wire weld kneeling	Work Phase 5 Re-arrange equip-ment	Work Phase 6 Change position
TOTAL Combination Posture Score	**2**	**1**	**1**	**2**	**2**	**2**
Common Posture Combinations (collapsed across work phases)						
Back	1	1	2	1		
Arms	2	1	1	1		
Legs	4	1	6	4		
Posture Repetition (% of working time)	48	14	20	9		
BACK % of Working Time SCORE	**1**	**1**	**1**	**1**		
ARMS % of Working Time SCORE	**2**	**1**	**1**	**1**		
LEGS % of Working Time SCORE	**2**	**1**	**1**	**1**		

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Table 42. Panel line welders OWAS (continued)

Risk Factor	Work Phase1 **Inspect**	Work Phase 2 **Grinding crouched/ kneeling**	Work Phase 3 **Change tool**	Work Phase 4 **Wire weld kneeling**	Work Phase 5 **Re-arrange equip-ment**	Work Phase 6 **Change position**
Posture						
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2	2	1	2	2	2
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	6	6	7	6	6	7
Load/ Use of Force						
1 = weight or force needed is = or <10 kg (<22lbs)	1	2	1	1	1	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)						
3 = weight or force > 20 kg (>44 lbs)						
Phase Repetition						
% of working time (0,10,20,30,40,50,60,70,80,90,100)	48	7	7	8	12	9

Table 43. Panel Line Welders PLIBEL

PLIBEL Checklist, Kemmlert (1995)

Date/ Time	Facility	Area/Shop	Task
4/17/00		Panel line	Panel Line Wire Welding

Section I: Musculoskeletal Risk Factors
Methods of Application:
1) **Find the injured body region, answer yes or no to corresponding questions**
2) **Answer questions, score potential body regions for injury risk**

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			Y	Y	Y
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 43. Panel Line Welders PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	Y				Y
f) handling below knee length	N				N
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	N	N			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		N			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 43. Panel Line Welders PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	13	6	3	3	10
PERCENTAGE	50	54.5	37.5	37.5	47.6

Section II: Environmental / Organizational Risk Factors (Modifying) **Answer below questions, use to modify interpretation of musculoskeletal scores**	
18: Is there no possibility to take breaks and pauses?	N
19: Is there no possibility to choose order and type of work tasks or pace of work?	N
20: Is the job performed under time demands or psychological stress?	N
21:Can the work have unusual or expected situations?	N
22: Are the following present?	
a) cold	N
b) heat	Y
c) draft	N
d) noise	Y
e) troublesome visual conditions	Y
f) jerks, shakes, or vibration	Y
Environmental / Organizational Risk Factors Score	
SUM	4
PERCENTAGE	40.0

E10.7 Table 44. Tank Grinders 1 RULA

Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

Date/ Time	**Facility**	**Area/Shop**	**Task**
7/26/99		Shipboard	Tank Grinding 1

RULA: Posture Sampling Results

RULA Component	**Frame # 30210 Grinding; disc (5 in)**		**Frame # 44640 Tool Change**		**Frame # 40470 Pad Change**		**Frame # 19710 Grinding; disc (3in)**		**Frame # 22080 Wire Brush**		**Frame # 60450 Needle Gun**	
	Specific	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*
Shoulder Extension/ Flexion	mod flex	3	neut	1	neut	1	sl flex	2	sl flex	2	sl flex	2
Shoulder is Raised (+1)		1		0		0		0		0		0
Upper Arm Abducted (+1)		0		0		0		0		0		0
Arm supported, leaning (-1)		0		0		0		0		0		0
Elbow Extension/ Flexion	neut	2	neut	2	neut	2	flx	2	neut	2	flx	2
Shoulder Abduction/ Adduction	neut	0	neut	0	neut	0	add	1	add	1	neut	0
Shoulder Lateral/ Medial	neut	0	neut	0	neut	0	mod med	1	mod med	1	neut	0
Wrist Extension/ Flexion	flx	2	neut	1	neut	1	ext	2	neut	1	neut	1
Wrist Deviation	ulnar	1	neut	0	neut	0	ulnar	1	rad	1	ulnar	1
Wrist Bent from Midline (+1)		0		0		0		0		0		0
Wrist Twist (1) In mid range **Or** (2) End of range		1		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		1		1		1
Arm and Wrist Force/ load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		1		1		2		2		2

Table 44. Panel line grinders RULA (continued)

RULA Component	Frame # 30210 Grinding; disc (5 in)		Frame # 44640 Tool Change		Frame # 40470 Pad Change		Frame # 19710 Grinding; disc (3in)		Frame # 22080 Wire Brush		Frame # 60450 Needle Gun	
	Specific	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*
Neck Extension/ Flexion		1		1		1		4		4		1
Neck Twist (+1)		0		0		0		1		0		0
Neck Side-Bent (+1)		0		0		0		1		0		0
Trunk Extension/ Flexion	neut	1	neut	1	neut	1	sl flx	2	sl flx	2	neut	1
Trunk Twist (+1)		0		0		0		0		0		0
Trunk Side Bend (+1)		0		0		0		1		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		1		1		1
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		1		1		2		2		2
Total Rula Score	**6**		**3**		**3**		**7**		**7**		**5**	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 45. Tank Grinders Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
Moore and Garg, 1995

Date/ Time	**Facility**	**Area/Shop**	**Task**
7/26/99		Shipboard	Tank Grinding 1

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**% MS** *(percentage of maximal strength)*	**Borg Scale** *(Compare to Borg Cr-10 Scale)*	**Perceived Effort**	**Rating**	**Multiplier**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**6.0**

Table 45. Tank Grinders Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: % Duration of Exertion = 100 x duration of all exertions (sec) Total observation time (sec) = 100 x 2726 (sec)/ 2988 (sec) = 91	**Rating Criterion**	**Rating**	**Multiplier**
	< 10	1	0.5
	10 - 29	2	1.0
	30 - 49	3	1.5
	50 -79	4	2.0
	> or = 80	5	3.0
Duration of Exertion Multiplier			**3.0**
3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: Efforts per Minute = number of exertions total observation time (min) = nearly static exertion, therefore **multiplier = 3**	**Rating Criterion**	**Rating**	**Multiplier**
	< 4	1	0.5
	4 - 8	2	1.0
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			**3.0**

Table 45. Tank Grinders Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	**Wrist Extension** *(Stetson et al, 1991)*	**Wrist Flexion** *(Stetson et al, 1991)*	**Ulnar Deviation** *(Stetson et al, 1991)*	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral (*estimated, based on RULAs performed)	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.5**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	**Compared to MTM** *(observed pace is divided by MTM's predicted pace and expressed as %)*	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	91 -100%	"normal" speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 45. Tank Grinders Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet: Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate @ 2-4 hrs)	***Rating Criterion***	***Rating***	***Multiplier***
	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**0.75**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**		**SI SCORE**
6.0 X	**3.0 X**	**3.0 X**	**1.5 X**	**1.0 X**	**0.75**	**=**	**60.8**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 46. Shipboard Tank Grinders UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
Lifshitz and Armstrong (1986)

Date/ Time	**Facility**	**Area/Shop**	**Task**
7/26/99		Shipboard	Tank Grinding 1

* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	**No**	**Yes**
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?	N	
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?		Y
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?		Y
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?		Y (grinder)
6.3 Is the handle of the tool made from material other than metal?	N	

6.4 Is the weight of the tool below 4 kg (9lbs)?		Y
6.5 Is the tool suspended?	N	
TOTAL	**14 (64%)**	**8 (36%)**

Table 47. Tank Grinders OWAS

OWAS: OVAKO Work Analysis System
Louhevaara and Suurnäkki (1992)

Procedure: Observe workers at intervals of 30-60 seconds. Record postures and forces over a representative period (~ 45 minutes)

Date/ Time	Facility	Area/Shop	Task
7/26/99		Shipboard	Tank Grinding 1

Risk Factor	**Work Phase1** **Grinding disc (5 in)**	**Work Phase 2** **Tool Change**	**Work Phase 3** **Pad Change**	**Work Phase 4** **Grinding disc (3in)**	**Work Phase 5** **Wire Brush**	**Work Phase 6** **Needle Gun**
TOTAL Combination Posture Score	**2**	**1**	**1**	**2**	**2**	**2**
Common Posture Combinations (collapsed across work phases)						
Back	1	1	2	1		
Arms	2	1	1	1		
Legs	4	1	6	4		
Posture Repetition (% of working time)	48	14	20	9		
BACK % of Working Time SCORE	**1**	**1**	**1**	**1**		
ARMS % of Working Time SCORE	**2**	**1**	**1**	**1**		
LEGS % of Working Time SCORE	**2**	**1**	**1**	**1**		

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Table 47. Tank Grinders OWAS (continued)

Risk Factor	Work Phase1 Grinding disc (5 in)	Work Phase 2 Tool Change	Work Phase 3 Pad Change	Work Phase 4 Grinding disc (3in)	Work Phase 5 Wire Brush	Work Phase 6 Needle Gun
Posture						
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	1	1	1	2	2	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	2	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	4	1	1	6	6	4
Load/ Use of Force						
1 = weight or force needed is = or <10 kg (<22lbs) 2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs) 3 = weight or force > 20 kg (>44 lbs)	2	1	1	2	2	2
Phase Repetition						
% of working time (0,10,20,30,40,50,60,70,80,90,100)	48	7	7	8	12	9

Table 48. Tank Grinders PLIBEL

PLIBEL Checklist, Kemmlert (1995)

Date/ Time	**Facility**	**Area/Shop**	**Task**
7/26/99		Shipboard	Tank Grinding 1

Section I: Musculoskeletal Risk Factors
Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	Y	Y	Y	Y	Y
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			Y	Y	Y
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			Y	Y	Y
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 48. Tank Grinders PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	N				
b) bent sideways or mildly twisted?	Y				
c) severely twisted?	N				
d) extended backwards?	Y				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	N				N
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	Y				Y
f) handling below knee length	N				N
g) handling above shoulder height	Y				Y
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	N	N			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		Y			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 48. Tank Grinders PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	14	9	5	5	11
PERCENTAGE	53.8	81.8	62.5	62.5	52.4
Section II: Environmental / Organizational Risk Factors (Modifying) **Answer below questions, use to modify interpretation of musculoskeletal scores**					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	N				
20: Is the job performed under time demands or psychological stress?	N				
21:Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	Y				
b) heat	Y				
c) draft	Y				
d) noise	Y				
e) troublesome visual conditions	Y				
f) jerks, shakes, or vibration	Y				
Environmental / Organizational Risk Factors Score					
SUM	6				
PERCENTAGE	60.0				

For more information about the
National Shipbuilding Research Program
please visit:

http://www.nsrp.org/

or

http://www.USAShipbuilding.com/